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"EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES, AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN"—SMITHSON

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CHAS. D. WALCOTT,
Secretary of the Smithsonian Institution.

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BY

A. G. MADDREN

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
PART OF VOLUME XLIX

Smithsonian Exploration in Alaska in 1904, in search of Mammoth and other fossil remains

BY
A. G. MADDREN

No. 1584.

CITY OF WASHINGTON
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SMITHSONIAN EXPLORATION IN ALASKA IN 1904 IN SEARCH OF MAMMOTH AND OTHER FOSSIL REMAINS

By A. G. Maddren

I. Introduction

The notes herewith presented are the result of an expedition to Alaska and adjacent territory made during the summer of 1904, under the direction of the Secretary of the Smithsonian Institution, through Dr. George P. Merrill, Head Curator, Department of Geology, U. S. National Museum. Conclusions are also in part based on observations made in 1899, when the writer travelled the length of the Yukon River; in 1900 when various points on the coasts of Bering Sea, eastern Siberia, and of the Arctic ocean as far east as Cape Beaufort were visited; and 1902-03 when a year was spent in residence on the Alaska peninsula. During these previous years ice in various forms was frequently noted, but not until the summer of 1904 was it made a special object of notice in relation to the Pleistocene deposits.

The object was to find, if possible, complete skeletons of the mammoth and other large extinct mammals reported as occurring in that region or at least a locality promising enough in its indications to warrant further investigation. This search was confined to the Pleistocene deposits of northern Alaska in which most of the Mammoth and other vertebrate remains occur. Hence the following observations treat of these formations and the criteria by which they are to be distinguished from the more recent ice and alluvial deposits which have been variously noticed and discussed by travellers and writers. The present writer has been able to verify many of the observations previously recorded and he hopes that the following review of the subject to date in the light of his own observations may elucidate some of the debated questions regarding the character and origin of the arctic Pleistocene deposits. The classification of the ice deposits, their relation to the Pleistocene, with the opinion concerning the ice beds of Eschscholtz Bay, about which there has been much discussion, is advanced tentatively with

the diffidence and reserve with which doubtful facts involving any generalization ought always to be expressed.

The problems of geographic distribution of the animal and vegetable life of North America in Pleistocene time with the disturbance of faunas and floras caused by the widespread glaciation during that period and their subsequent readjustment over the glaciated area, all combine to form a complex arrangement, to solve which will require large collections of specimens from the Pleistocene deposits of the unglaciated area of Alaska and the adjacent Canadian territory. For at present our knowledge of this fauna and flora is very limited. As far as we know, only one species of elephant (*Elephas primigenius*), the Mammoth, inhabited Alaska and Siberia during Pleistocene time.

In 1850 Dr. C. C. A. Grewingk[1] brought together all the records then known of the occurrence of Mammoth remains in Alaska. On pages 290 and 291 of the 1850 edition of his work he summarizes this information. On pages 78 and 79 he gives a review of the discovery of Mammoth remains on Eschscholtz Bay by Kotzebue in 1816, and on pages 81, 82, and 83 presents the results of Beechey's expedition to that locality in 1826. He refers the elephant remains enumerated by Buckland to *Elephas primigenius* and doubtfully to *Elephas indicus.*

He continues: "Mastodon ribs, tibia, and tusks of *Elephas primigenius* and *E. indicus* (?) were collected by Wossnessenski from Cape Nugvulinuk (near Tolstoi Point), Norton Sound."

"Mastodon bones and tusks are common along the coast between Bristol Bay and Norton Sound (see Veniaminoff, Notes on the Unalaska District, St. Petersburg, 1840, p. 105); furthermore they have been found on the Pribilof Islands, and lastly also on Unalaska (Island) according to Dr. Stein."

On page 68 he says: "On a stream having the same name as this cove (apparently Golsova river of present maps, Topanika Creek of Dall) were found in alluvial deposits of clays and sands, the ribs, tibia, and tusks of *Mastodon* which were collected by Wossnessenski in 1843 and sent to the Academy of Sciences (at St. Petersburg)."

"These specimens appear to resemble the living elephant more closely than they stand to the mammoth."

[1] Beitrag zur Kenntniss der orographischen und geognostischen Beschaffenheit der Nord-West Küste Amerikas mit den anliegenden Inseln. Verhandl. Russ. k. mineral. Gesell. zu St. Petersburg, 1848, 1849, also separates, 1850.

On page 124 "and in Dr. Stein's memoir (Trudi Mineral, Obs. CII, 1830, pp. 382, 383) it is stated that somebody, probably a Promishlenik (a trader), found *Mammoth* tusks and molar teeth on Unalaska Island in 1801." On page 190 "Mammoth tusks were found on the island of St. George (Pribilof group) in the year 1836 according to Veniaminoff."[2]

It may thus be seen that Grewingk makes no distinction between the terms *Mammoth* and *Mastodon* and apparently is not satisfied that the fossil elephant of Alaska is the typical *Elephas primigenius* of Siberia.

Later Dall[3] appears to accept this latter view of Grewingk and mentions that Wossnessenski collected tusks, teeth, and bones of the *Elephas primigenius* and *Elephas columbi* near Topanika Creek, Norton Sound. We think the identification of *E. columbi* needs verification before it is assigned to Alaska. M. T. Obalski[4] mentions the occurrence of the *Mastodon* in the placer gravels of the Klondike region, but this statement, which the writer understands is not based on the identification of specimens, appears to be an error. Obalski makes another statement that does not appear to be founded on fact. He says ivory tusks 6 meters (19.6 feet) long occur in the Klondike gravels. This statement is an exaggeration. The longest tusk so far reported from Alaska is one 12 feet 10 inches (about 4 meters), measured along the outside of the curve. Remains of the rhinoceros have not been reported with those of the mammoth in Alaska, as in Siberia, and it also appears that the remains of the mammoth in Alaska are not in as fresh a state of preservation as those found in Siberia, which points to the surmise that the mammoth became extinct in Alaska before the last of the species succumbed in Siberia. Associated with the mammoth were herds of large bison and horses. This species of horse may have been the last native to North America, the rear guard of the last migration of these animals across the region of Bering Straits to Asia before the land connection disappeared. There was a species of musk-ox together with sheep and bear. Descendants of these last three forms have by adaptive changes survived in these northern regions down to the present time.

The relation that the fauna and flora north of the area occupied

[2] Notes on the Unalaska District, St. Petersburg, 1840, I, p. 106.

[3] Report on Coal and Lignite of Alaska. Seventeenth Ann. Rep., U. S. Geol. Survey, 1896, p. 856.

[4] Les grand Mammifères fossiles dans le Yukon et l'Alaska. Bull. du Mus. d' Hist. Nat., Paris, 1904, No. 5, pp. 214-217.

by glaciers bore to that in the region of the United States before, during, and after separation by the snow and ice fields; also the relation of forms in Alaska to those of Siberia, with the time and duration of the land connection across Bering Straits and their subsequent separation, form a complex problem, the solution of which will require the accumulation of much material.

The writer takes this opportunity to express his thanks to the members of the staff of the U. S. Geological Survey engaged in Alaska for valuable suggestions; especially to Mr. A. H. Brooks, in charge of geological work in Alaska, for the use of data presented on the accompanying map together with the photographs used as illustrations, and to Mr. A. J. Collier for looking over the manuscript.

II. ITINERARY

The party consisted of the writer and one man employed as camp-hand and boatman; the plan being to employ natives for additional labor as found necessary. We travelled by steamer from Seattle, Washington, and arrived at Skagway, Alaska, May 28. Thence by rail over White Pass to the town of White Horse, Northwest Territory, Canada, the terminus of the railway and head of steamboat navigation on the Yukon River. Here we were delayed several days waiting for the water of the river to rise sufficiently to allow stern-wheel steamboats which draw twenty-six inches of water to proceed down stream. We left White Horse June 6 and reached Dawson June 8. Our inquiries here pointed toward the fact that no complete skeletons of mammoth have been found in the mining diggings of the Klondike, though scattered fragments of this and other Pleistocene mammals are of common occurrence as will be mentioned later. Without delay a "poling" boat thirty-five feet long was purchased and with this, travel was continued down the Yukon.

Circle City was reached on June 18. Here inquiry was made to learn the identity of the "Kotlo River" of Dall.[1]

[1] This name was first used by Dall to designate a stream shown on his map, published in "Alaska and Its Resources" in 1870, and also in Bull. 84. U. S. Geol. Surv., 1892, pl. III, draining the general area of the valley of the present Birch Creek and indicated by him as emptying into the Yukon about thirty miles below the site of the present settlement of Circle. The writer was informed that a little-used Indian portage exists across the low bottoms of the Yukon Flats from the Yukon to Birch Creek on approximately the same route marked by Dall for the lower course of the "Kotlo" river and undoubtedly in compiling his map he misinterpreted information intended to convey the location of this portage for the course of a river.

It was found to be the stream shown on recent maps of Alaska as Preacher Creek, so named by pioneer prospectors after the Rev. R. McDonald, Chaplain of the Hudson Bay Company and missionary to the Indians, who first reported the occurrence of placer gold in the basin of this stream. Preacher Creek is a tributary of Birch Creek, which flows into the Yukon River about thirty miles below Fort Yukon. Under the name of "Kotlo" River Dall reports Preacher Creek as a locality where Mammoth remains occur in abundance. This report was substantiated, but we did not make a personal investigation since we were told by Indians of a much more promising locality on Old Crow River, a tributary of the Porcupine. As there was not time to visit both localities we chose the latter because of assurances that the abundance of fossil mammal remains on the Old Crow River far exceed those of any other locality known to the Indians of this region, whom it must be conceded are in position to be best informed about matters pertaining to remote parts of this region.

We arrived at Fort Yukon at the mouth of the Porcupine River on June 21 to find an epidemic of diphtheria prevailing among the Indians of this settlement, causing much alarm by the number of deaths resulting from the disease, and making it impossible to procure guides or adequate assistance for the trip up the Porcupine River. A scarcity of essential provisions also existed here at this time owing to the retirement from business of the only commercial establishment at this place at the time of our visit. This made it necessary to prosecute the journey up the Porcupine away from any other source of supply without sufficient supplies for an extended period of work. We left Fort Yukon with about one hundred and twenty pounds of provisions the most conspicuous item of which was fifty pounds of flour; the remainder being made up of rice, beans, bacon, sugar, tea, and a few pounds of dried fruit. With fish, geese, and two caribou we were able to shoot, this amount proved sufficient for two persons for forty days, but the time was not sufficient to permit of a thorough exploration of the Old Crow basin. In fact it was found possible to make only a very preliminary examination.

Through fortunate cooperation with a white trapper, who was ready to ascend the Porcupine to his winter hunting ground, we were enabled to continue with the large boat purchased at Dawson, but after reaching the Ramparts where our companion wished to stop, we were compelled to exchange this large boat, which proved too heavy for two persons to propel with the ease essential to the rapid progress necessary under the circumstances, for a canoe.

The ascent of the Porcupine was commenced June 23, progress being made by "tracking" and "poling." The lower one hundred and twenty-five miles of the Porcupine, from Fort Yukon to the Lower Ramparts, flows by a tortuous course through the low forested region known as the Yukon Flats. Its course forms a series of curves of one to three miles' radius alternately sweeping from right to left, the channel being entirely confined by banks of unconsolidated alluvium nowhere exposing rocks older than Pleistocene age. The banks are of an average height of about twenty feet above the normal level of the river, but are seldom sufficiently elevated to prevent their overflow by the spring floods. The difference of level between the mouth of the Porcupine and a point one hundred and twenty-five miles above produces a gradient over which a torrential current is only prevented by the extremely tortuous course followed by the river over its flood plain. The current averages about three miles an hour through this part. It presents the typical features of meandering erosion, cutting away the banks on the concave side and depositing the material removed lower down on the opposite convex side or bars. These bars are quite shallow in most cases and being frequently strewn with stumps and stranded trees necessitate continuous wading on the part of the "trackers" with the attendant annoyance of the tow-line frequently becoming fouled with entangling branches, roots, etc. These features present a marked contrast in the character of the banks. Those of the outer curves are precipitous, owing to the undermining and consequent crumbling of the banks. Being frequently covered with a thick growth of spruce the river cuts a path through the forest leaving the trees standing as grain does beside a clean cut swath. Frequently the sections give exposures of solidly frozen peaty layers and also the edges of lenticular beds of clear flood-plain ice. The shimmering silence of the nightless days of summer in these arctic solitudes is often harshly broken by crashing splashes along these undercut banks where massive blocks of frozen earth topple over with their incumbent trees to disappear with muddy gurgles beneath the silt-laden current. In plate 1, fig. 1, is shown a cut bank in Yukon Flats, with timber and overhanging mantle of tenacious turf characteristic of all river banks of Alaska where unconsolidated deposits are undermined by the current.

On the inside of the curves are the low, gently sloping banks of recent flood-plain deposits known as bars. In typical sequence these are current-bedded gravels succeeded at a higher level by sand beds which in turn pass beneath deposits of fine silts. The gravels

Photo. by Collier.

1. Cut Bank in Yukon Flats.

Photo. by Collier.

2. Bluffs of Pleistocene Silts below Lake Lebarge, Yukon River.

are deposited by the swift waters along the border of the main channels while the finer superimposed strata are laid down in the slack water on the inner margins of curves during flood stages, and it is here that pieces of ice floating down on the spring floods become stranded as the waters recede, and melting deposit any freight in the shape of fragments of fossil bones, teeth, etc., that may be frozen within or borne upon them. Below the level of flood these bars present a surface of gravels, sands, and mud bare of vegetation but strewn over with stumps, logs, and drift brush. Back of this comes a strip covered with grasses and a variety of equisetum called "goose-grass" because it forms the chief food of these birds during their molting season. Above this belt comes a growth of young willows which as they recede from the river increase to a height of twenty to thirty feet. Mingled with the willows and replacing them on the landward side are clumps of alders and groves of poplars which in turn are succeeded on higher, better drained lands by spruce forests extending away to mingle with the birch growing on the distant hills. Below the depth of a foot or two the soil is everywhere frozen.

Above the Yukon Flats the Porcupine flows from a considerably contracted valley called "the Ramparts." This is a name introduced by the northern fur-traders to designate a contracted, walled, or cañon-like valley and has been applied by them to similar physiographic features on the Mackenzie, Porcupine, and Yukon rivers. On the Porcupine, Upper and Lower Ramparts are differentiated and the portions of the valley so named are very picturesque. In passing through the Ramparts the river contracts considerably, not exceeding seventy-five yards in width in places. The current becomes more rapid, flowing from three to four and a half miles an hour with occasional short riffles where the velocity is much greater, being estimated at seven or eight miles per hour, but there are no obstructions or rapids which would prevent a small light-draft steamer with requisite power from navigating the river (plate 1).

The change in topography in ascending from the Yukon Flats into the Lower Ramparts is ushered in gradually by a belt of Pleistocene deposits several miles wide rising thirty to fifty feet above the river, followed by several ranges of low hills leading up to the abrupt walls of the entrance to the contracted portion of the valley. The river flows through the Lower Ramparts for about twenty-five miles. The rocky walls, generally disconnected and low, are composed for the most part of limestones seldom abruptly developed on both sides of the river so as to form a cañon. Thus a shore is

presented along which one is able to "track" with only occasional interruptions at precipitous places, where it becomes necessary to carry the tow-line along the top of a cliff or force the canoe against the swift eddies invariably occurring at these places by vigorous use of the oars accompanied by dexterous manipulations of the "pike-pole."

Above the Lower Ramparts the river swings in wide sweeping curves as it flows for about twenty-five miles through an alluvial channel across a basin filled with Pleistocene silts, down into which it has cut about one hundred feet. These silts appear to fill the basin of a former fresh-water lake that was barricaded from the extensive Yukon Flat Basin to the west by the low range of the Lower Ramparts and bounded on the east by the higher plateau of the Upper Ramparts. While this basin does not present a great width where the Porcupine flows across it there is every indication that it occupies considerable areas both north and south of the Porcupine and that the considerable stream called the Coleen drains the area occupied by the northward extension of these sediments. For this reason it appears convenient to designate this area of Pleistocene sedimentation between the Lower and Upper Ramparts as the Coleen Basin. The sediments are unconsolidated silts, sands, and gravels and in one exposure thin seams of lignite were observed. Older rocks similar to those of the Lower Ramparts with some basalt occasionally outcrop along this reach. After making a wide bend to the north through which the channel is divided by alluvial islands with strong currents the valley contracts again to abrupt bounding walls. The rocks here are a massive basalt that forms the western limit of the Upper Ramparts. The walls are higher and more abrupt than those of the Lower Ramparts. They rise from three to five hundred feet above the river and extend to a point about twenty miles above the international boundary or approximately sixty miles. As is to be expected the river follows a more direct course across this area of hard rocks. It is through this part the river contracts to its narrowest dimensions and reaches its greatest velocities. The basalt extends upstream apparently as a continuous sheet for about thirty miles or nearly to the boundary line between Alaska and Canada. This basalt sheet edged with vertical cliffs is the conspicuous feature of the river for this distance. The valley gorge is bounded by even, precipitous walls carved out of this rock, which from their dark color lend a sombre appearance to the landscape. The lower surface of the basalt undulates as the older underlying rocks rise or descend along the bottom of the

valley. The uniformity of the walls is also broken at intervals by deep gashes cut by tributary streams through the basalt sheet. Above the upstream limit of the basalt sheet low mountains rise a short distance back from the valley walls near the boundary line. From here to the upper limit of the Ramparts the green slopes which replace the basalt walls are frequently broken by shattered pinnacles, bold crags, and minarets of brilliantly tinted rocks.

About ten miles above the lower entrance to the Upper Ramparts, opposite the mouth of Salmon-Trout River on a small bench of Pleistocene fluvial sediments that rise about forty feet above the river level, the Hudson Bay Company formerly maintained a trading post called Rampart House. Later this settlement was moved up the Porcupine about thirty miles to remove all doubts about its position in regard to the boundary line. This establishment was designated New Rampart House and the former site was known as Old Rampart House. New Rampart House is situated a short distance east of the 41st meridian of longitude that separates Canada from Alaska and about two hundred and ten miles by river from Fort Yukon at the mouth of the Porcupine, on an elevated bench of Pleistocene silts similar to that where the older post was located. These are the only two areas of such deposits of any extent throughout the Upper Ramparts. The Hudson Bay Company have discontinued trading posts on the Porcupine River for the past eight or ten years and for this reason apparently it has been abandoned by Indians, who now frequent it only upon occasional hunting excursions.

Above the Upper Ramparts which terminate about twenty-five miles east of the international boundary the river meanders out into another basin filled with Pleistocene silts. This area appears to be much more extensive than the Coleen Basin and the designation Bluefish Basin is suggested for it because it appears to be drained largely by that river. The Porcupine flows along its northwest margin, the channel frequently abutting directly against the old limestone formation of the Upper Ramparts, the higher extension of which along the north side of the valley forms the Old Crow Mountains, the summits of which attain elevations of about two thousand feet along the river. The river presents the same features as already described for its course through the Yukon Flats and the Coleen Basin except that greater thicknesses of silts are exposed. Here they rise to heights of one to two hundred feet above the river and present almost vertical exposures on the concave sides of the banks. On some of these high bluffs elevated ice-beds were

observed and the ability of the cliffs to maintain their vertical fronts appeared to be due to the fact that their mass is solidly frozen. It was noted that bluffs facing the south appear, under long exposure, to thaw out sufficiently to allow their escarpments to crumble down into gentle slopes. Shallow quicksand bars were encountered along the thirty miles below the mouth of the Old Crow River.

The Old Crow River flows from the northwest into the Porcupine about sixty miles above New Rampart House. It enters the main river with a bluff along its right bank that exposes hard dark shales rising about twenty feet above the river for half a mile, overlaid by one hundred and fifty feet of the unconsolidated Pleistocene silts already described. Its left bank is bounded by a low wooded flat extending east across the mouth of the valley to a range of high hills about five miles distant. As we ascended this river the following features were noted. After passing for ten miles through a flood plain eroded across the above mentioned silts three distinct terranes have been exposed by the down cutting of this stream. As one ascends the river these are, first, a series of limestones, intersected with calcite veins, extending for about eight miles; then a belt of granitoid rock that confines the river to a gorge estimated to occupy about five miles of its course; and third, an outcrop of sandstones or quartzites three or four miles wide. This series of hard rocks extend, apparently as an anticlinal uplift, across the lower part of the Old Crow Valley to connect the mass of the Old Crow Mountains, bounding the north side of the Porcupine Valley to the west, with a low range of mountains that trend to the northeast to bound the expanse of the Old Crow Basin on the east. Before the river cut through this ridge of rocks it formed the lowest part of the southeastern rim of a large Pleistocene lake that had an approximate extent of one hundred miles north to south with a width of sixty miles east to west. Today this former lake area lies as a vast elevated undulating plain surrounded by mountain ranges on all sides. Its frozen lacustrine silts have been dissected to the depth of one to two hundred feet by the Old Crow River and its tributaries, which meander through this extensive flat basin in the most intricate manner, presenting many examples of former wanderings in the occurrence of crescent shaped lagoons or ox-bow lakes at present flood-plain and higher levels.

The lower banks support dense growths of willows and alders while the higher levels are interspersed with shallow lakes, groves of poplars, considerable patches of spruce, and a scattered growth of birch. The two latter kinds of tree are confined mostly to the higher, better drained areas.

The course of the Old Crow River was ascended about one hundred and seventy miles by following its winding series of incredible and complicated curves, though the extreme point reached was estimated to be not over half that distance from the mouth of the river in a straight line. Along their southern margin the unconsolidated deposits that fill the Old Crow Basin present at first a terrane such as is to be expected along the shore of a lake. Considerable thicknesses of gravels and sands were noted for about fifteen miles, until passing more towards the center of the basin area the sediments changed to homogeneous gray clays in which gravel was totally absent, and where only small quantities were occasionally observed on the bars associated with fragments of fossil mammal bones that have been deposited during spring floods by floating ice from the headwaters of the river. As the course of the river winds through these frozen silts it generally presents bold escarpments along the concave sides of the curves, with muddy bars overgrown by dense thickets of willows opposite. It is on the tops of these high silt bluffs the beds of elevated ice are exposed and their more recent relation to the silts themselves so clearly demonstrated.

These ice-beds are not extensive sheets covering large areas but rather restricted masses, rarely exposing over one-half mile of continuous ice, that appear to be frozen ponds, ox-bow, or other lakes, that remained in the low parts of the undulating surface of the lake bottom when it was drained. As their mode of origin and formation will be discussed later we may pass them with the statement that the Old Crow Basin presents this phase of elevated Pleistocene silts with ice on top developed to a greater extent than the writer has seen or read of anywhere else. Beds of ice were observed as far as we were able to ascend the Old Crow River. They appeared on top of the banks, always at elevations of one hundred or more feet above the stream, for a distance of more than one hundred miles along the stream and no doubt continue to the northern limit of the basin. The ice varies greatly in color, structure and thickness. Some is of a brownish hue having much the same color as peat water and containing quantities of comminuted vegetable matter, in some parts distributed evenly through the mass, and at other places concentrated in thin layers like sheets of paper between thicknesses of clear ice. Some is whitish and granular, especially at its surface, and often contains numerous cavities of gas bubbles. At other places masses of green and blue ice were observed. In some exposures all three kinds of ice are associated within one hundred

yards of each other with all intergradations of physical characteristics represented. All this goes to show that apparently there is only one criterion upon which to base a classification of the ice deposits of these northern regions, and this is, *position.*

During the first week of our ascent of the Old Crow the river steadily subsided. As the waters became lower widely scattered parts of the skeletons of the large fossil mammals we were searching for, were left exposed on the clay banks below high water mark. In this way several of the large leg bones of the mammoth together with specimens of its teeth and bones of horse and bison were picked up. About one mile above the mouth of the first tributary coming into the Old Crow from the left we found the badly mutilated skull of a mammoth. It showed every evidence of rough treatment by the ice of one or more spring break-ups. The tusks were absent and their sockets badly broken away, the teeth were gone, and it was clearly evident that this skull had come from a considerable distance upstream. We left it on the water's edge imbedded in the tenacious gray clay. When we returned to it a week later on our way down stream it was covered by six feet of water. For after leaving that spot on our way upstream we daily experienced heavy rains, frequently accompanied by thunder, that appeared to originate in the mountains surrounding this basin and give that particular area the whole benefit of rainfall. In consequence the country became inundated, caused the river to rise very rapidly, and also increased the current so as to make upstream progress slower. Finally on July 23 an inventory showed about six pounds of flour, a couple of handfuls of tea with some partly dried deer meat not in too savory a state of preservation, to be the remaining stock of provision. This with the fact that we were about four hundred miles from the nearest settlement, Fort Yukon, determined us to turn back. It was with much reluctance we did so for nearly every mile of the last one hundred travelled on the Old Crow River had yielded increasing evidence, in the shape of a tooth, a horn core, or a bone lying on the banks below high-water mark, of the existence of deposits containing considerable remains of the skeletons of large Pleistocene mammals. Every mile of the last one hundred was travelled with the expectation of discovering a place of primary entombment of these remains. Under the circumstances it became necessary to abandon further exploration with the hope of returning another year to fully investigate this locality. It was on this river the remains of mammoth were reported to be abundant, and as we have just pointed out, all the

evidence coming under our observation leads to the conclusion that an extensive deposit of large Pleistocene mammal remains, represented principally by mammoth, bison, and horse, exists on the headwaters of the Old Crow River.

In 1873 Rev. Robert McDonald presented a collection of remains of Pleistocene mammals to the British Museum. The locality given for them is the Upper Porcupine River and it is probable a more definite locality for this collection may be the Old Crow River, a tributary of the Porcupine. They have been enumerated by Lydekker in the Catalogue of Fossil Mammalia in the British Museum, Part II, pages 26, 27, 39, 78, 86, and 87; Part IV, page 204. Leith-Adams also mentions three left lower molars of the mammoth from this collection in his work on British Fossil Elephants, page 117.

Our return to Fort Yukon, by the same route we had ascended the river, was accomplished in eight days, and beyond one mishap, in which our canoe rolled over in a shallow riffle, that resulted in the loss of two sacks of bones that were not lashed in the canoe, together with some photographic plates that became wet, was accompanied by no extreme inconvenience.

The journey down the Yukon River was continued to examine other localities reported as productive of Pleistocene mammal remains. This necessitated travelling by steamer and small boat alternately. A locality about thirty miles below Fort Hamlin on the right bank of the Yukon was visited as was also Little Minook Creek near the town of Rampart where elevated fluvial sediments containing scattered Pleistocene mammal remains occur. From Fort Gibbon where the Tanana River joins the Yukon the trip was continued by small boat to give opportunity of stopping at the "Palisades" or so-called "Bone-Yard" about thirty-five miles below.

This locality is described by Russell,[6] later by Spurr,[7] and also by Collier.[8]

The escarpment called the Palisades is from one hundred and fifty to two hundred feet high, composed mostly of fine, light colored, unstratified silts. Back from the bluff is a level, densely wooded table land, with swamps and ponds, bordered on all sides, except that adjacent to the river, by low hills. The Palisades proper are washed by the river and are bare precipitous bluffs of frozen silt.

[6] Notes on the Surface Geology of Alaska. Bull. Geol Soc. Am., Vol. I, 1890, p. 122.

[7] Geology of the Yukon gold district. Eighteenth Ann. Rep. U. S. Geol. Survey, pt. 3, 1898, pp. 200-221.

[8] Bull. No. 218, U. S. Geol. Survey, 1903, pp. 18 and 43.

This fact accounts for their steep face. The same escarpment extends some ten miles up the river, with a wooded flood plain along its base. There is a little ice on top of these bluffs but nothing like the extensive development exposed in the Old Crow Basin. The under-cutting of the river causes large slabs and blocks of the frozen silts to fall into the river and it has been reported that numbers of bones, teeth, and tusks are thereby exposed, which has given this locality the name of "Bone-Yard." The writer found only a few scattered fragments in 1904 (pl. II, fig. 1).

G. M. Dawson says:[a]

"In 1886 the Geological Survey of Canada acquired from Mr. F. Mercier, who had spent many years as a trader in the Yukon region, a number of bones, tusks, and teeth of the Mammoth. These were chiefly obtained by Mr. Mercier near the mouth of the Tanana River." It is probable the "Palisades" is the locality where these specimens were gathered.

The Palisades form a typical exposure of the lacustrine phase of the deposits Spurr and Collier designate the "Yukon Silts" and which Dall has called the "Kowak Clays." They are for the most part of Pleistocene age as is shown by the bones of mammoth and other large mammals besides the shells of freshwater and land molluscs represented by living species contained in them. All phases of "Yukon Silts" grading from coarse gravels to clays are distributed as fluvial and lacustral deposits throughout the Bering Sea and arctic drainage basins of Alaska and adjacent territory. Their elevation and dissection by the present streams has produced the bluffs and terraces that form such a conspicuous feature along most of the rivers.

At a settlement called Kokrines, steamer transportation was resumed to Kaltag, a small trading post where the government telegraph line and winter mail trail that extends down the river leaves the Yukon, ascends Kaltag river to near its head, then crosses the divide to Unalaklik River, and descends that stream to Norton Sound, a total distance of about one hundred miles. At Kaltag the services of two natives as packers and guides were engaged and on August 14 with two additional Eskimos engaged to pack for the first fifty miles, the party commenced an overland trip which occupied thirty-one days and extended, for nearly three hundred miles, across the drainage basins of the Ungalik, Inglutalik, and

[a] Quart. Jour. Geol. Soc., Lond., Vol. 50, p. 2, see also Lambe in the Ottawa Naturalist, Vol. XII, Oct. and Nov., 1898, p. 136.

Koyuk rivers. The camp equipment for this trip was reduced to a minimum. It consisted of a tent made of balloon silk weighing twelve pounds, measuring eight feet square on the floor, with a waterproof canvas ground cloth. A light robe made of four large caribou skins, sewed together, served as a common mattress for all, and a blanket apiece completed the bedding. Three kettles, a frying pan, with a tin cup and spoon apiece were all the utensils found necessary. The provisions carried, exclusive of the supplies required for the two additional packers, consisted of one hundred and fifty pounds of flour, thirty pounds of rice, thirty pounds of beans, sixty pounds of bacon, twenty-five pounds of sugar, three pounds of tea, two pounds of baking powder, and two pounds of salt. Three hundred pounds altogether or seventy-five pounds to each man, or an average of two and a half pounds per man per day. This supply, supplemented by a few fish and a number of ptarmigan shot from day to day with a light 22 caliber rifle carried for this purpose, proved ample. With the help of the two additional packers engaged to accompany the party the first fifty miles, who returned to Kaltag, no difficulty was experienced in making satisfactory progress. The greatest annoyance experienced was that caused by the frequent rains that made the swollen streams difficult to ford.

The route, indicated on the accompanying map, was followed in the hope of locating a place of primary interment of mammoth remains where there might be the likelihood of obtaining a skeleton. We were unsuccessful in the desired object, observing only scattered depositions of bones and teeth, and these not in quantity that offer much promise of future success in finding a complete skeleton in this area. An Eskimo village called Isaac's on Norton Bay was reached September 14 and passage to St. Michael secured on a small trading schooner. From here Nome was reached on September 20 by local steamer.

In the curio shops at Nome we found many sections of mammoth tusks in a good state of preservation, said to have been obtained on King Island, which lies in Bering Sea about forty miles southwest of Port Clarence. An attempt was made to secure passage to King Island, but as the stormy autumn season was advanced and the island affords no landing or shelter to an approaching vessel, an examination into the occurrence of these remains had to be postponed. For the same reason a visit to the historic locality on Eschscholtz Bay, Kotzebue Sound, was found impracticable. We therefore took passage by ocean steamer from Nome on October 9 and Seattle, Washington, was reached on October 20.

III. THE FIELD OF SEARCH

I. PRIMARY AND SECONDARY DEPOSITIONS

All the recorded occurrences of Pleistocene mammal remains in Alaska and adjacent Canadian territory known to the writer are what may be termed, for convenience, *scattered* depositions. That is, in no case known may we be sure in stating that the remains are found where the animal actually died and was entombed. It is true some of the specimens of bones examined are in such good condition they cannot have travelled far from their original place of deposition. But on the other hand all of the material found is dismembered and the bones scattered, while most of it is water-worn and shows other evidence of having travelled, in some cases considerable distances. These scattered depositions of remains occur as separate bones, teeth, tusks, skulls, horns, etc., throughout both the Pleistocene and recent lacustral and fluvial formations. No *original* interment, that is, where the approximately complete remains of skeletons occur within reasonable compass, of any Pleistocene mammal is known, to the writer, to occur in Alaska or adjacent territory. But certainly such original or primary deposits must have existed and some of them may be found intact if sufficient search is made for them.

We may note the occurrence of scattered remains of the mammoth on some of the islands in Bering Sea. The Pribilof group has yielded the most evidence. In 1836 it is said a tooth was found on St. George Island,[10] and a tusk has been reported from St. Paul Island. Stanley-Brown says:[11] "There are two fragments of paleontologic evidence connected with the islands which, as they have been used by writers, demand a cautionary word. The tusk of a mammoth was found in the sands of Northeast Point on Saint Paul Island, and the tooth of one is reported as coming from the shores of Saint George. As there is not a foot of earth on either island, save that which has resulted from the decomposition of the native rock and the decay of vegetation, the value of such testimony is questionable."

Dawson[12] makes reference to these occurrences of mammoth remains and appears to favor the view that they are derived from

[10] Dall. Bull. 84, U. S. Geol. Survey, 1892, p. 266 and Seventeenth Ann. Rept. U. S. Geol. Survey, 1896, p. 858.

[11] Bull. Geol. Soc. America, Vol. 3, 1892, p. 499.

[12] Quart. Jour. Geol. Soc. London, Vol. 50, 1894, p. 6.

animals that actually lived on what are now the islands. More recently fresh evidence has come from this group. "Mr. F. A. Lucas[u] noted 'the Occurrence of Mammoth Remains on the Pribilof Islands,' stating that Mr. R. E. Snodgrass and the party from Stanford University had, in 1897, obtained two teeth of the Mammoth and bones of a bear, apparently distinct from the existing Polar Bear, from a lava cave on Bogoslof Hill (St. Paul Island). He was of the opinion that possibly the presence of these bones in such a situation might indicate the comparatively recent connection of the island with the mainland."

Mr. Bristow Adams, artist to the Fur Seal Commission that investigated the Condition of the Pribilof Islands in 1897, was one of the discoverers of this cave and the remains above mentioned. In a conversation with the writer he says: The cave is apparently formed by a contraction of the lava that forms the entire mass of Bogoslof Hill, which is about six hundred feet high and at least one-half mile from the nearest part of the seashore. The cave is up well towards its top. The cavity is not a large one, for its greatest dimension is not over forty feet and its height only about eight or nine feet. It has two openings. A large one in the roof about six feet in diameter by which nothing might enter the cavity without making a shear drop of twelve feet and by which it is impossible to make an exit; and a small opening at one end barely large enough for an average sized man to squeeze through. It was by this smaller opening the party entered the cave. The floor of the cave was entirely composed of pulverulent organic humus and it was from this the mammoth teeth and bear bones were disinterred. The depth of the humus floor deposit was not determined and as only a limited time was spent in the cave no extensive excavations were made. The remains found were situated at the end of the cave farthest from the openings as if they had been dragged there. As it is not stated whether the mammoth teeth are those of the upper or lower jaws we are unable to say whether the evidence points towards the presence of the whole skull or only the lower jaw of the animal in the cave. It seems impossible that the skull of the mammoth could have been dragged into the cave and remains of it not be found with the teeth, but it would be an easy matter for a detached lower jaw to be transported to the cave by a bear.

With these facts we leave each one to draw such conclusions as may suit his fancy. But we suggest that it will require more evi-

[u] Science, Nov. 18, 1898, p. 718.

dence than is afforded by this occurrence of mammoth remains to justify the assertion that the Pribilof Islands, as they stand today, have ever been part of a continental area during the time the mammoth lived, and we must not be too hasty in picturing the elevation of the northeastern portion of Bering Sea 300-400 feet that " would convert most of the present sea bottom into a vast verdure-covered *tundra,* whose gentle undulating surface would be dotted with lakes and intersected by sluggish winding streams." Though such an elevation of the land to form a connection between Asia and Alaska, with migration to the south in North America cut off by a barrier of glaciers, would throw these two regions into the same faunal province and appears to have been the condition that prevailed at some time, we are far from sure that the outflows of eruptives that entirely form the Pribilof group,[14] where every scrap of physical and petrographical evidence indicates the recency of the islands' formation, existed at an early enough date as a land surface for mammoths to roam over them. These islands have probably risen quite recently from the shallow sea floor.

It is well to remember that the two most indestructible structures of the mammoth skeleton are the teeth and tusks and that these are the parts found most widely scattered through recent deposits because, on account of their hardness, they will stand more frequent transportation by ice and water. Such remains may be carried from the streams of the continent in spring by ice and be drifted for miles about the sea, by currents or the gales that prevail at that season, to the shores of islands.

There is also the record already given from Grewingk that Dr. Stein [15-16] reported the discovery of teeth and tusks of the mammoth on the island of Unalaska in 1801. In 1904 the writer saw sections of mammoth tusks in the curio shops at Nome that had been polished and carved by the Eskimo of King Island in Bering Sea. The fact that natives from that place sold these to dealers in Nome is the basis for the statement, by the dealers, that the ivory comes from King Island, but it appears most likely that the tusks were obtained from the Alaskan mainland, which is visited each summer by these islanders, and carried to their settlement for the purposes of manufacture and thence to Nome for sale.

Mr. E. A. Preble of the U. S. Biological Survey informs the

[14] For an account of the geology of the Pribilof Islands see Stanley-Brown, op. cit.

[15-16] Trudi mineral Obst., St. Petersburg, 1830, pp. 382, 383.

writer that in a museum maintained at the Hudson Bay Company's post at Fort Simpson on the Mackenzie River he observed teeth of the mammoth *(E. primigenius)*. These specimens have no definite localities assigned them, but it is presumed they were found in the region of the lower Mackenzie Valley.

In this connection it appears opportune to call attention to a fact that apparently has been lost sight of by recent observers on the ethnology of the Alaskan Eskimo. This is the use by these people of a *blue pigment* derived from the decomposition of mammoth tusks. Sir John Richardson makes a note of this in his work on the Zoology of the Voyage of H. M. S. Herald, 1854; page 61, he says: "Several of the mammoths' tusks also have exfoliated, and a beautiful blue phosphate of iron has formed between their plates. This is evidently the blue pigment used by the native tribes on the coasts of Beering's Sea, and which has passed from tribe to tribe by barter in small quantities as far as the banks of the Mackenzie. It is mentioned by Cook, but its origin was unknown until now. Dr. Davy had the kindness to analyze this substance at my request, and he found that the first portions I sent to him were accompanied by a greater proportion of carbonate of lime than a recent tusk should contain. The iron may have been derived from the red gravel bed, associated with the bones; * * * * * * Having sent a second specimen of a decaying tusk to Dr. Davy, he says, 'It is stained by peroxide of iron without any phosphate. I cannot find in it any mass of carbonate of lime. The proportion of animal matter in it is large, sufficient to preserve the form of the fragment after the removal of the phosphate of lime by an acid. Probably complicated affinities are engaged in the production of the blue phosphate, and carbonate of iron is concerned (not carbonate of lime). Perhaps the protoxide of the carbonate may combine with the phosphoric acid of the bone (ivory), and the carbonic acid of the former with the lime of the latter; the animal matter present in the bone in clay preventing the higher degree of oxidation.'"

IV. THE GLACIAL PERIOD AND THE MAMMOTH

I. RUSSELL QUOTED

Without entering into a discussion of the geologic time limits of the mammoth in Alaska it is well to note the facts in regard to its geographic range and that of the great glaciers. I. C. Russell[17] is

[17] Notes on the Surface Geology of Alaska. Bull. Geol. Soc. America, Vol. I, 1890, p. 123.

the first observer to call attention to this: "It is an interesting fact that all the bones of the mammoth and of other large animals that have been found in Alaska occur, as far as I am aware, in regions not glaciated during the Pleistocene period. The relation of mammoth remains to the distribution of glaciers in Alaska acquires additional importance in view of the fact that no evidence of glaciation has been reported in northern Siberia, where similar mammalian remains are also abundant.

"The study of glacial records by various observers has shown that the great Pleistocene glaciers of this continent extended outwords in all directions from two main centers of accumulation, one in Labrador and the other in the northern part of the Rocky Mountain region. During their greatest extension these two great glacier systems seem to have been confluent so that a vast ice field stretched across the continent from ocean to ocean. The northward movement of the ancient ice sheet was not sufficient in all places to reach the Arctic ocean (see map). In view of this fact, it may be suggested that the abundance of mammalian bones is due to the crowding northward and final extinction of land animals of the Pleistocene period by the advance of continental glaciers from the south."

2. DAWSON QUOTED

G. M. Dawson[18] substantiates Russell's observations in "Notes on the Occurrence of Mammoth remains in the Yukon District of Canada and in Alaska." He says in part:

"The writer in 1887 travelled through the valleys of the Pelly and Lewes rivers, but did not go below the confluence of these streams. In the whole region thus traversed no Mammoth remains were met with nor was their presence reported by such of the goldminers as had worked in parts of these valleys; though some of the same men had frequently noted Mammoth bones farther down the Yukon valley, particularly in the vicinity of Forty-Mile Creek.

"Within the area which was covered by the great Cordilleran Glacier, remains of the Mammoth are either entirely wanting or are very scarce. The reported finding of a tooth on the southern part of Vancouver Island, and a portion of a large bone of doubtful determination in gravels worked for gold on Cherry Creek, Okanagan District, British Columbia, are the only possible exceptions known to the writer."

The tooth from Vancouver Island may no doubt be referred along

[18] Quart. Jour. Geol. Soc., Lond., Vol. L, 1894, pp. 1-9.

with a tooth from Whidby Island, Washington, and now in the U. S. National Museum, to *Elephas columbi* and not to the true Mammoth *(Elephas primigenius)*. Several additional occurrences of scattered mammoth remains within the general limits of glaciation are the part of a tooth found in the drift about six miles above Edmonton, Alberta, Canada,[19] and on Snow River, at the head of Lake Kenai, Kenai Peninsula, Alaska.[20]

In Science[21] under the heading "Geographical Notes," an anonymous writer mentions that Lieut. H. T. Allen observed remains of mammoth, presumably, on the Copper River, Alaska. This appears to be an error, for Lieut. Allen[22] makes no reference to such remains having been seen on the Copper River, but he says, that on the Koyukuk River, which flows into the Yukon from the north, six miles above the mouth of the Allenkakat River, a tributary of the Koyukuk, he found the *os pubis* of a mammoth. He also makes a note on his map No. 1, of "Ice banks—Mammoth remains" at the mouth of a stream he names the "Atutsakulakushakakat" that flows into the Yukon from the south about eighteen miles below the mouth of the Tozi River. This is the general locality of the Palisades already mentioned.

V. HORIZON OF MAMMOTH IN ALASKA

1. REMAINS CARRIED OUT ON LAKES BY FLOATING ICE

The lowest horizon in Alaska to which Mammoth remains may be referred are the lacustrine facies of the "Yukon Silts" or the "Kowak Clays."[23]

These deposits form an extensively developed Pleistocene feature in Alaska. Scattered through them occur fragmental remains of mammoth skeletons, isolated teeth, tusks, and bones, which are exposed where the streams undermine the silts by lateral cutting.

[19] Lambe: The Ottawa Naturalist, Vol. XII, 1898, p. 137.

[20] The Nome Semi-Weekly Nugget, Sept. 24, 1904.

[21] Vol. VI, October 30, 1885, p. 380.

[22] Report on an Expedition to the Copper, Tanana, and Koyukuk rivers in Alaska in 1885. Senate Ex. Document, 2d Session, 49th Congress, 1886-'87, Vol. 2, p. 99.

[23] For a description of these deposits see Spurr, Geology of the Yukon gold district. Eighteenth Ann. Rep. U. S. Geol. Survey, pt. 3, 1898, pp. 200-221.

Collier, Bull. No. 218, U. S. Geol. Survey, 1903, pp. 18 and 43.

Dall, Bull. 84, U. S. Geol. Survey, 1892, pp. 265-266 and in a Report on the Coal and Lignite of Alaska, Seventeenth Ann. Rep. U. S. Geol. Survey, 1896, p. 856.

The fragmental condition and scattered positions of these remains places them in the category of *secondary depositions.* The state of preservation of bones from these situations indicate they have not been carried far. Generally they are unbroken (pl. II, fig. 2).

2. SEARCH FOR SKELETONS SHOULD BE MADE ON LAKE SHORES

That the fluvio-glacial Pleistocene lakes of Alaska were subject to annual winter freezing, at least at various stages of their existence, there appears no doubt, because scattered apparently indiscriminately through the clays at varying depths and considerable distances from the former shore lines of these basins are some mammal remains. Their positions can only be accounted for by supposing they were carried out on the waters of the lakes from the adjacent shores or tributary streams by ice during spring breakups and freshets, there to be dropped by its melting to their present positions interbedded in the silts. There appears no other logical way of explaining the presence of these bones in the lacustrine areas. While their presence under these circumstances points towards the lakes freezing over in winter we do not wish it understood by this that Alaska then had winters as severe as those of the present time, or that it was ice bound for the greater part of each year, but that conditions were more nearly as they are in temperate regions today. The main point is that the remains occur in the silts as scattered depositions. The animals from which they are derived probably died about the shores of these lakes and it is these Pleistocene lake shores we must examine carefully if we are to obtain anything like complete remains of the mammals inhabiting the region at that time.

VI. PLIOCENE IN ALASKA

I. DEPOSITS. PROBABLE CHANGES OF LEVEL

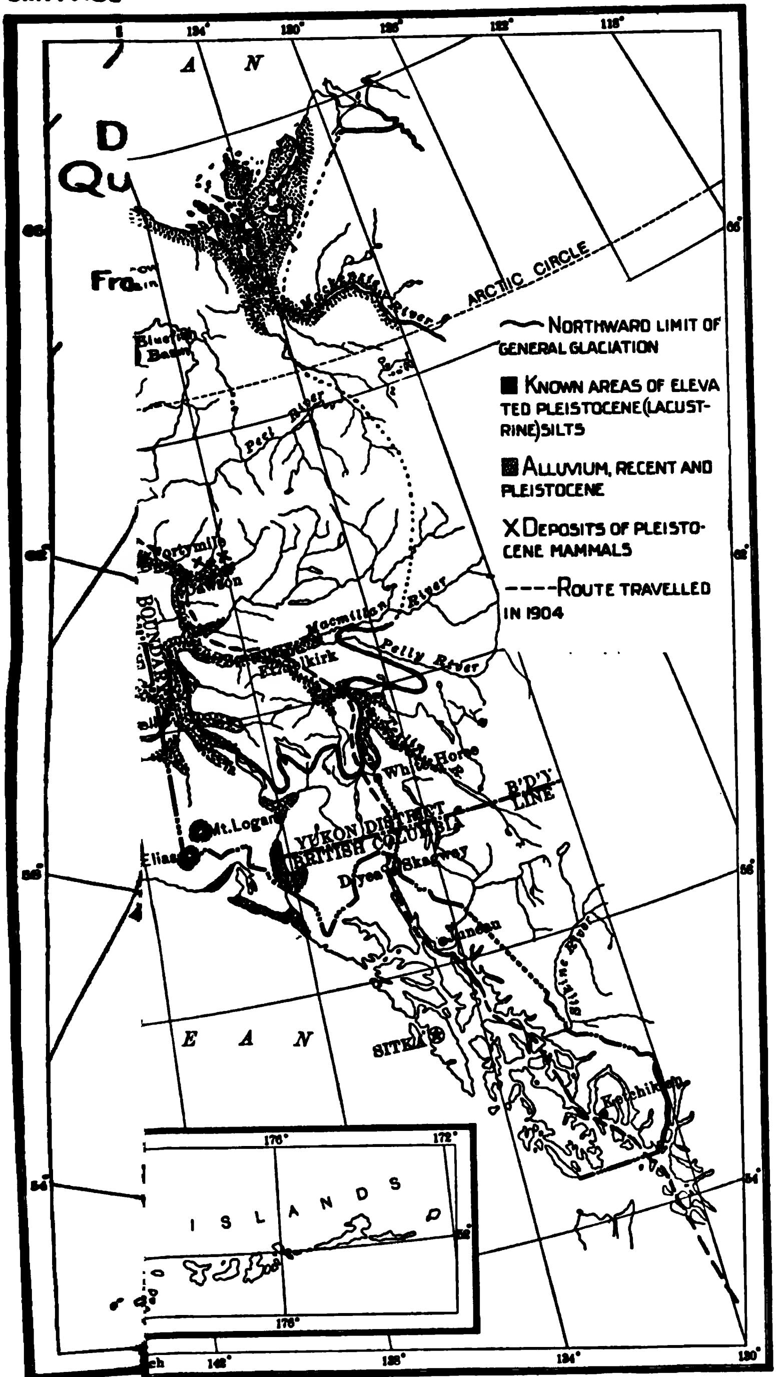
No extensive developments of Pliocene have been identified in Alaska. Whether Pliocene time was mostly one of denudation over this great area, ending with a subsidence accompanied by changes in relief forming barriers across the main drainage courses of the country, which in some cases appear to have been augmented by flows of eruptives, remains to be shown. At any rate there were barriers that localized the retention and deposition of the Pleistocene lacustrine silts and clays throughout the drainage basins in the majority of cases. In other instances the coarser silts along valleys appear to have formed by a clogging of the channels by

Photo. by Collier.

1. Palisades on the Yukon River thirty miles below the mouth of the Tanana River, showing blocks of frozen silts as they are undermined and subside into the river.

Photo. by Collier.

2. Pleistocene Silt Bluff on the Klalishkakat, a tributary of the Yukon, showing a mammoth tusk protruding from the bank.


NORTHWARD LIMIT OF GENERAL GLACIATION
KNOWN AREAS OF ELEVATED PLEISTOCENE (LACUSTRINE) SILTS
ALLUVIUM, RECENT AND PLEISTOCENE
X DEPOSITS OF PLEISTOCENE MAMMALS
----ROUTE TRAVELLED IN 1904
ARCTIC CIRCLE
Peel River
Macmillan River
Pelly River
Dawson
Mt. Logan
YUKON DISTRICT
BRITISH COLUMBIA
B'D'Y LINE
Dyea
Skagway
SITKA
ISLANDS
E A N
A N

the Pleistocene sediments where remnants of them remain today hanging to the valley sides. Whether these changes belong to the later Pliocene or early Pleistocene remains to be settled.

VII. GRAVELS UNDERLYING PLEISTOCENE SILTS

Underlying the Pleistocene silts in some places are gravel beds whose possible Pliocene age has been suggested by Spurr (Geol. Yukon Gold District, 18th. Ann. Rep. U. S. Geol. Sur., Part 3, p. 199). But from the relation they bear to the silts in the Old Crow Basin, where the gravel terrane forms a typical beach deposit contemporary with the lacustrine silts it appears they may be considered of the same age.

VIII. BRIEF OUTLINE OF PLEISTOCENE OF ALASKA

1. MAP

In order to show more clearly how these scattered and original depositions of mammal remains occur, a sketch of the nature, distribution, and extent, of the Pleistocene, with such reference to the Recent as concerns the Mammoth will be attempted.

Through the kindness of Mr. Alfred H. Brooks, Geologist in charge of the U. S. Geological Survey work in Alaska, the writer is enabled to present a map of Alaska showing the latest results of the field observations of members of that survey as regards the Quaternary. This map (pl. III) shows the boundary between the southeastern glaciated and the northwestern non-glaciated areas within Alaska, together with the distribution of the unconsolidated sediments forming the Pleistocene and Recent. However, this limit while practically a continuous line must not be interpreted as the limit of a continuous ice-sheet, but of individual glaciers. The areas occupied by the "Yukon Silts" and "Kowak Clays" are differentiated in a general way as far as known. These silts and clays have special significance and are no doubt more numerous and extensive than here shown.

2. STRATIGRAPHIC RELATIONS OF PLEISTOCENE

The fluvial and lacustrine beds of Alaska and the adjacent unglaciated portion of Canada represent the whole Pleistocene period. The silts with their occasional gravels rest unconformably on the eroded surfaces of the older formations. They appear most conspicuously as terraces along the sides of the valleys. Where the

valleys widen into basin-like expanses there are typical lacustrine deposits. They are made up of unconsolidated grayish colored sands and clays sometimes underlain by gravel beds which appear to be of contemporaneous age. These silts may usually be differentiated from the Recent alluvium by their lighter color, which also suggests their fluvio-glacial origin. As recognized and described by observers the Pleistocene occurs as deposits of gravels, sands, and clays distributed throughout the drainage basins. In Alaska, as in Siberia, no inter-Glacial deposits appear to occur, and the relations of the fluviatile and lacustrine deposits to the glacial accumulations of the mountains, beyond the general fact that most of the materials of the former are the down-stream residual of the latter, cannot be stated at present.

3. DERIVATION. NATURE. DISTRIBUTION

The events that lead up to their deposition appear to have been a period of general erosion, for the unconformable underlying surfaces of the older rocks are swept clean, and then a time of land depression making transportation and deposition the chief work of the rivers. This subsidence diminished the flow of the drainage, reducing the current to such an extent as to form lakes where there was room for them. Fluvial deposits were laid down along the valleys and lacustrine silts in the expanded basins. Some of the drainage courses were obstructed at intervals by elevations of the older strata and others by flows of basalt that appear to rest directly on the eroded surfaces of the older rocks, thus demonstrating their age, though relatively young, to be older than the silts. In the basins thus formed the finer silts were laid down, while in some cases there appear to have been areas of relatively quiet water caused by the channels through the extensive flood plains clogging with sediment. Thus at the time the "Yukon Silts" and "Kowak Clays" were forming, Alaska, for the most part, was a low-lying country, characterized by enlarged rivers with slow drainage and many lakes. The supply of water was abundant and the flood plains extensive. The present valleys were the drainage channels for the volumes of water that flowed from the great glaciers to the south and east and from the local glaciers within its limits. All these waters were highly charged with silt and the finer sediment was carried far beyond the glaciated areas where today they lie deposited in former lake basins and along the valleys.

The silts are from fifty to two hundred or more feet in thickness and at the "Palisades" on the Yukon and in the Coleen Basin on the

Photo. by Collier

1. Ground sluicing a deposit of flood-plain ice on a placer mining claim on the Seward Peninsula. Alaska. Such ice masses overlain by humus and soil are called "*glaciers*" by the miners.

Photo. by Hess.

2. Bar ice on the Yukon River in June overlain by gravels deposited by the flood of the spring break-up.

Porcupine, beds of lignite occur interstratified showing a local drainage or elevation of these basins in the course of their silting up and then further subsidence and deposition.

As noted by Spurr[34] and Collier[35] "The silts, though entirely unconsolidated, are in places thrown up into broad, open folds, and at one locality faulting was observed."

4. SNOWDRIFT OBSTRUCTION OF DRAINAGE

None of the facts as now exhibited in Alaska make it necessary to resort to fanciful pictures of the flood plains of the drainage systems being modified or obstructed by great accumulations of winter snows, either to account for the lacustrine nature of the Pleistocene silts themselves or for the deposits of ice found on top of, but *never interstratified* with, them. Geikie[36] refers to Darwin as having suggested "that valleys might eventually become entirely filled with the blown snows of successive years, so as to compel the rivers in summer to rise in flood, and to reach levels which they might otherwise have been unable to attain. That such changes may have taken place again and again is no mere dream." On page 665 Geikie concludes: "We are justified, therefore, in the belief that the drainage systems in the low grounds must frequently have been deranged by the presence of such congealed snowdrifts," etc.

5. PLEISTOCENE LAKE BASINS

The Pleistocene lake basins in Alaska were formed by barriers across the general drainage systems as they exist today. The barriers vary in nearly every case. The lakes necessarily did not all become barricaded at the same time. In fact there is reason to believe that in different areas these barriers formed obstructions to the general drainage at varying periods throughout the Pleistocene. Consequently the silt deposits, though similar otherwise, because of common origin, are not all of the same age. Neither were all the Pleistocene lakes drained at the same time, for some of the barriers were more resistant to the erosion that set in with the elevation that closed the period and were not cut down sufficiently until a considerable time after other areas were drained. It is in the last drained areas that the remains of elevated ice are freshest.

[34] Geol. Yukon Gold Dist., 18th Ann. Rep. U. S. Geol. Sur., Part 3.
[35] The Coal Resources of the Yukon, Alaska, Bull. U. S. Geol. Sur., No. 218.
[36] Great Ice Age, p. 663.

The sequence of events accompanying the period of elevation and drainage cannot be traced in detail with the facts at hand. They are mentioned here to show there is no necessity for calling in " unusual accumulations of snow throughout successive years " to account for any of the phenomena under consideration.

6. ELEVATION AND DEFORMATION AT CLOSE OF THE PLEISTOCENE

It has already been stated that the Pleistocene silts of Alaska are thrown up into broad open folds. These undulations appear best developed where there are the largest areas of silts or throughout the basin areas of the former lakes. The deformation appears to have developed during the period of elevation that marked the close of the period of Pleistocene deposition. This folding was gentle and formed comparatively small shallow lake and pond areas over the drained bottoms of the former extensive lakes.

7. PROBABLE CHANGE OF CLIMATE

Accompanying this elevation was a change from comparatively mild, temperate conditions, which there is every reason to say existed—for the fauna and flora as far as known demand moderately temperate conditions—to the climate that prevails in these regions today.

As a better idea of the situation may be presented by quoting from one who has given considerable attention to the subject the following is appended from Sir Henry Howorth [n] in an article entitled " The Mammoth Age was Contemporary with the Age of Great Glaciers ; " he says : " It is a remarkable fact that if we limit ourselves to the plains of northern Siberia, there is no evidence that a period of severe cold other than that now existing has marked the climate of Siberia since the Mammoth was extinguished. The existence of carcasses in their flesh point to the age they represent having been the last one, the climate having become more and more severe since the Mammoth age. This means, if evidence is to go for anything, that the Mammoth age in Siberia and northeast Europe, which was its last epoch, was contemporary with the Great Glaciers." He quotes Geikie as saying " the Mammoth and the Woolly Rhinoceros may have survived in northern Asia down to a comparatively recent date " [o] and continues : " I cannot see how the conclusion can be avoided, in fact, that in Siberia the Mammoth

[n] Geol. Mag., Lond., 1894. pp. 161-167.
[o] The Great Ice Age, 3d ed., pp. 706-707.

age was strictly contemporary with the development of Great Glaciers in Europe and North America."

"What is true of Siberia is equally true of that outlier of Siberia —Alaska—which resembles it in every way, in the preservation of remains of Pleistocene beasts in a very fresh condition, whose very freshness, as in Siberia, points to their having lived in the very latest geological period, and contemporaneously with the glaciation of the country round Hudson's Bay further east."

On page 164:[29] "If we turn to America and examine the problems, either as presented by the so-called bone licks of Ohio, or by the driftless areas, we shall be constrained to the same conclusion. The bones of the extinct animals in both cases occupy the very latest beds and are found, so far as we can judge, at the precise horizon where elsewhere the drift beds occur."[30]

On page 167:[31] "The view here urged in regard to the contemporaneous existence of the Great Glaciers and a fertile champagne country side by side in the last geological age seems to me to best explain the facts."

"What I do dispute is the inference that they point to the Ice beds being older than the Mammoth beds. Whatever their age, it seems to be quite certain that they must be the result of infiltration, unless trees can grow on blue ice and Mammoths browse on snow."

Further, Howorth[32] remarks:

"To shortly state the general conclusions which I would press:

"I. During the Pleistocene period the Arctic lands, instead of being overwhelmed by a glacial climate, were under comparatively mild conditions, and were the home of a widely spread and homogeneous fauna and flora constituting, perhaps, the best defined life-province in the world.

"II. Since Pleistocene times the climate of these Arctic lands has been growing more and more severe, resulting in the extinction of a portion of their vegetable and animal inhabitants.

"III. The true and the only Glacial climate which we know to have prevailed in the Arctic lands was not during the so-called Glacial age of geologists, that is during the Pleistocene period, but in that which is now current, and which is the product largely, if not

[29] Op. cit.
[30] See Geikie, The Great Ice Age, p. 464.
[31] Op. cit.
[32] The Recent Geological History of the Arctic Lands, Geol. Mag., Lond., 1893, p. 500.

entirely, of changes of level in the earth's crust which have occurred since Pleistocene times."

Howorth's ideas as above expressed are supported by the facts in Alaska as far as known, particularly in his contention that the Ice beds, or so-called "Ground-ice formation" of Dall, or "Fossil-ice" of Baron Toll, did not precede the Mammoth age and, therefore, does not belong to the Pleistocene period.

How generally accepted is the opinion that the Ice beds are older than the Mammoth may be gathered by the following from Geikie:[33]

"There cannot be any doubt, therefore, that this remarkable sheet of dead ice must date back to Pleistocene times, and is obviously of the same origin, as Dr. Penck remarks, as the frozen bottoms or grounds which are so commonly met with in the higher latitudes of North America and Asia. Since the Mammoth and its congeners disappeared, no similar accumulation of ice has formed in that region —the dead ice is not being added to, but is gradually wasting away, and Dr. Penck[34] is clearly right when he says that the ice masses of Eschscholtz Bay belong to an older period, when the climate of those northern regions was considerably colder than it is to-day. The frozen grounds of the far north are, in short, the equivalent in time of the old glacial phenomena of our temperate latitudes. The ice masses of northern Alaska are not the relics of any glacier or ice sheet, for we have no reason to believe that those tracts have ever been glaciated. They simply represent the drifted snows of Glacial times which accumulated in valleys and depressions outside of the ice-covered regions. Protected under a covering of alluvial matter, soil, and peat, they have, in those high latitudes, endured to the present day."

It appears strange that "the drifted snows of Glacial times" should have collected and been preserved only in situations that were at that time without question the bottoms of Pleistocene lakes covered with water.

Thus it is easy to see that the significance of these ice beds has puzzled inquirers a great deal and explanations of their origin hardly less discordant with the facts than those recorded above have been entertained and defended.

[33] The Great Ice Age, 3d ed., p. 665.

[34] Deutsche geographische Blätter, Bd. IV, p. 174.

IX. DEPTH OF FROST IN CIRCUMPOLAR REGIONS

I. STATEMENTS BY RUSSELL

Russell[33] says: "The reason for the great thickness of the frozen layer at these localities seems to be that deposition and freezing went on at the same time. These certainly seem to be the conditions under which the great thickness of frozen material beneath the tundra and in the flood plains of the larger rivers of Alaska have accumulated.

"It seems to me that this must also be the explanation of the origin of all frozen deposits which contain alternating strata of clear ice and of frozen layers of mud and peat like those exposed in the borders of the tundra and along the banks of the Yukon.

"It is recorded by K. E. von Baer that the ground at Yakutsh, Siberia, is frozen to the depth of 382 feet. It has been assumed by various writers that the great depth of ice (frost?) in this and other similar instances is due directly to *surface temperature,* the downward limit to which the winter's cold can penetrate being limited by the internal heat of the earth. Before accepting this explanation as final it should be ascertained whether the strata at the localities where depth of frozen material has been encountered might not have been frozen progressively as they were laid down."

In the Pleistocene lacustrine silts and clays as exposed today to depths of at least one hundred and fifty feet we have examples of deposits of homogeneous material without any interstratification of ice or any other material being in a frozen state. These clays could not freeze while being deposited under water. Consequently they have assumed a frozen state since the waters of the lakes have been drained off. And the cold that caused this freezing is the same that has frozen the ice beds now lying conformably on top of the clays.

On page 130 (op. cit.) Russell gives a mathematical presentation of the subject by R. S. Woodward:

"The considerable depth below the earth's surface to which frost or the temperature of freezing is known to penetrate in the Arctic regions, raises the interesting question of the relation between the thermal properties of the earth's crust and the time and depth of penetration, etc."

"The conclusion reached by Mr. Woodward indicates that the

[33] Notes on Surface Geology of Alaska. Bull. Geol. Soc. Am., Vol. I, p. 129.

freezing of even the deepest ice stratum reported in the Arctic might have resulted directly from a mean annual temperature no lower than *now prevails* in northern Alaska."

The writer thinks it safe to reiterate that the most severe climate we are justified by facts in assigning to the Arctic is that prevailing there today.

Page 132 (op. cit.) "Although the passage of heat through the surface layers in Arctic regions is slow, yet it is apparent that the length of time since a mild climate existed there is sufficient, even under existing conditions, to allow of the freezing of strata several hundred feet below the surface. The mean annual temperature of the non-glaciated portion of Alaska during the Glacial epoch must have been lower than at present—at least such I am confident would be the conclusion of the majority of geologists—and there seems good reason for believing that the freezing of the tundra began in Pleistocene times and continued to the present day. An increase in the thickness of the frozen layer, owing to the influence of a mean annual temperature below 32° F., and the deposition of a succession of frozen layers, as suggested elsewhere, may have combined to produce the results now observed."

The writer cannot agree with the supposition that "The mean annual temperature of the non-glaciated portion of Alaska during the Glacial epoch must have been lower than at present." There are no facts to support such a view. Neither is this surmise justified—"and there seems good reason for believing that the freezing of the *tundra* began in *Pleistocene time* and continued to the present day"—for there is nothing to show that a tundra mantled surface of the non-glaciated area was the condition prevailing in Pleistocene time. In Siberia the flora of Pleistocene time north to the present Arctic coast line was not what is classed as tundra. In Alaska, too, the Pleistocene lignites tend to show that a more temperate flora extended considerably farther north than today and there is nothing to indicate that tundra existed at all until the Recent period commenced. The writer considers that all of the peat and tundra of Alaska belongs to the Recent. That the climatic conditions inaugurating this period were the first of enough severity to suppress vegetation to the character called tundra.

2. A. C. SEWARD QUOTED

A. C. Seward[38] under the heading, "Plants and Low Tempera-

[38] Fossil Plants as Tests of Climate. Cambridge Univ. Press, London, 1892, p. 44.

tures: Arctic Vegetation," summarizes as follows: "In attempting to picture to ourselves the conditions which obtained during the Glacial period, it is frequently forgotten that a very low temperature is not of that importance which it is often considered to be in bringing about an Ice Age.

"Wallace[37] and many others have laid stress on the necessity for a concurrence of several conditions in order to render possible an abnormal extension of snow and ice.

"Whitney[38] in his comprehensive monograph on the climatic changes of later geological times, has argued for the possibility of the former extension of snow and ice without any violent changes in climatic conditions.

"After considering the question at length he remarks, 'The entire body of facts presented brings out most clearly the true condition of things, namely, that the Glacial epoch was a local phenomenon, during the occurrence of which much the larger of the land masses of the Globe remained climatologically entirely unaffected.' As illustrating the possibility of glaciers existing in places whose mean temperature differ by several degrees we may notice some observations given by Woeikof.[39] He shows clearly how other conditions than merely a low temperature are essential to ice extension. Comparing the temperature taken at the lower ends of glaciers in East Siberia and the west of New Zealand, there is found to be a difference of more than 20°; at Irkutsk in East Siberia the temperature recorded being —10.2°, in New Zealand 10°. Glaciers occur in the latitude of Nice and Florence extending to 212 meters above the sea level having at their lower ends a mean annual temperature corresponding to that of Vienna and Brussels, and warmer than that of Geneva and Odessa, with a winter temperature higher than that of Florence.

"There is the often-quoted case of the Tasman glacier descending towards the West coast of New Zealand; here the terminal face of the ice is 705 feet above sea level, and is 'hidden by a grove of Pines, Ratas, Beeches, and arborescent Ferns in the foreground.'

"All these facts show us that the idea of the coexistence in the same region of vegetation—in some cases of an almost tropical facies—and ice fields is not so inconceivable as one might suppose.

[37] Island Life.

[38] The climatic changes of later geological times. Mem. Mus. Harvard Coll., Vol. VII, No. 11, 1882, p. 387.

[39] Gletscher und Eiszeiten in ihrem Verhältnisse zum Klima. Zeit. Gesell. für Erdkunde zu Berlin, Vol. XVI, 1881, p. 217.

A brief sketch of some of the conditions of plant life in Arctic lands will further make this clear, and at the same time bring out a number of facts which have an important bearing on the question of plants and climatic conditions," etc.

X. THE LAND ICE OF ARCTIC AND SUB-ARCTIC REGIONS

Ice deposits may be classified under five heads in chronological sequence as follows:

1. GLACIAL ICE OF SNOW ORIGIN

Glacial ice does not enter into this discussion beyond what has been already said; that its erosive action in the higher lands produced most of the immense quantity of detritus which forms the deposits of the Pleistocene period, and the waters from the melting snow and ice supplied the great volumes necessary to transport this material over the wide areas it now occupies. The ice in this case is of snow origin and its formation has extended from Pleistocene time down to the present.

2. ICE-BEDS OF ELEVATED PLEISTOCENE LAKE BASINS NOT OF SNOW ORIGIN

The older elevated ice-beds as they survive in Alaska today appear to mark the end of the Pleistocene and beginning of the Recent, there being no break between the two periods. This elevated ice marks a colder climate, which accompanied the elevation of the land that drained the large Pleistocene lakes. It also marks the beginning of conditions as they exist today in that region. It is the oldest ice we know of after glacier ice.

The ice-beds are elevated from fifty to two hundred feet above present drainage levels. They rest on the Pleistocene lacustrine clays in hollows or undulations apparently due to gentle folding the silts have undergone in being elevated to present levels. This same elevation being the one that has caused the Pleistocene lakes to drain.

As already remarked it is dead ice gradually wasting away and not, from appearances, being added to in any way. Generally it may be distinguished from the younger ice interstratified, or rather intermingled, with the recent alluviums of the river and coastal plains, by its occurrence in more extensive sheets or beds, its elevation above the present drainage levels caused by the down-cutting of the streams since it was frozen, and in that it rests conformably

upon the Pleistocene lacustrine silts. If a snowdrift deposit, some evidences of unconformity are to be expected. For naturally snowdrifts are likely to sometimes collect on land surfaces thus burying the vegetation previously growing on the land and preserving some trace of it underneath any future beds of ice the snow might form. Some evidences of vegetation are to be expected under the ice-beds where they formed on or near the former lake shores, but the remains in such cases are entirely different from those that snowdrifts might bury. There appears to be no reason for confusing such occurrences. At Eschscholtz Bay the remains of vegetation associated with the silts and ice are composed of sticks and twigs of trees, some of them gnawed by beavers. This is an occurrence to be expected on the shores of lakes in estuaries and near the mouths of small streams. As before stated, when the Pleistocene beds were elevated, and the former lakes drained, the deposits were thrown into gentle folds, and no doubt some irregularities of bottom already existed, such as may be accounted for by irregularities in the deposits due to cross-currents and wave building forming areas favorable for the retention of shallow ponds and lakelets; also ox-bow lakes which are common today in these regions. The hollows of the undulating surface formed shallow basins of varying areas, with impervious clay bottoms. The new land surfaces thus laid bare were diversified by a large number of shallow lakes and ponds spread over the formerly extensive lake bottoms. Today the old dead ice-beds appear to be consistently associated with impermeable clay basins in elevated positions.

The more severe climate that appears to have gradually accompanied the elevation of the land froze these shallow basins of water into the ice-beds we see today. Just as the large lakes were not all drained at the same time neither did the freezing of the ice-beds happen contemporaneously but progressed gradually as it does today. I. C. Russell* describes the process. The surface of the new land was carpeted by a layer of moss that surrounded the ponds and lakes. The moss encroached on the lakes from all sides. "As the moss covers the lakelets more and more completely during a series of years, the ice formed by the freezing of the water in winter is more and more thoroughly protected, and is finally completely shielded from the heat of summer. A body of clear ice is thus formed in the tundra, similar to the strata of ice exposed at certain

*Notes on the Surface Geology of Alaska. Bull. Geol. Soc. Am., Vol. I, 1890, pp. 99-162.

localities along the coast of Bering Sea and in the banks of the Yukon."

The older elevated ice-beds of the Pleistocene lake basins apparently have been covered and preserved in this way. As exposed today by the lateral cutting of the streams draining their areas the ice-beds have a covering of peat varying from two or three to fifteen feet in thickness. In most cases this protective covering to the ice is composed entirely of vegetable remains. It is only rarely that recent alluvium or soil is incorporated with the peat or humus covering. This is because of the relative positions of the ice-beds with reference to drainage levels that have existed in these areas from the time they formed to the present. This absence of alluvium above these elevated beds of old ice—when examined at the places of their typical development, that is, out on the undulating Pleistocene lake bottoms—distinguishes them from the newer, less extensive occurrences of ice intermingled with the materials of the present flood plains, that are subject to annual overflows and consequent depositions of alluvium.

Only where the ice masses formed near the shore lines of the former lakes, and in places where the land rises more or less abruptly, may we expect to find alluvium derived from the nearby slopes on top of the ice or incorporated with its humus covering.

The ice phenomenon at Eschscholtz Bay seems to be clearly an example of former lake-shore conditions as is also the locality on the Beresowka River in northeastern Siberia described by Tolmatschow.[a]

3. COASTAL-PLAIN ICE-BEDS. NOT OF SNOW ORIGIN

The significance of coastal-plain ice-beds is not clear to the writer. They are not elevated to such a height nor as uniformly or extensively as the beds in the elevated Pleistocene lake areas. They are not of snow origin or we should expect to see the process of their formation going on today. Some tentative suggestions are offered. These deposits occur, as far as known, along the Arctic coast and only in areas that have undergone comparatively recent heavy sedimentation. It is reasonable to suppose that the shifting of the mouths of the rivers and the consequent change of areas of loading have caused a shifting of regions of depression and upheaval during Quaternary times. Thus shallow lakes, bays, or sounds resulted, according to the extent of the uplifting. Wave and floe-ice

[a] Verhand. der Kaiser. Russ. Min. Gesell. Bd. XL, Lief. 2, 1903.

action, together with warping of the sea floor when raised up or unequal sedimentation before elevation above sea level, may also perform a significant part in the formation of ridges that eventually act as barriers to land-locked bodies of water. It is probable the changes of elevation along the coast that have raised and exposed the coastal-plain ice-beds are due to the shifting of the loading point areas of the rivers. None of the exposed ice beds in coastal-plain deposits in Alaska are reported to exceed elevations over thirty or forty feet above the sea level.

Under the conditions of climate and vegetation that have existed along the Arctic coast during the Recent period, ice-beds might be formed in a manner similar to the apparently older elevated ice-beds occurring in the Pleistocene lake areas.

It does not appear that the ice beds along the Arctic coast of Alaska have the continuous or extensive development Dall claims for them, as shown on his map, plate III, Bull. No. 84, U. S. Geol. Survey, 1892; nor with the statement, quoted, from whaling captains, made in his report on "The Coal and Lignite of Alaska:"[a]

"At a depth of two feet is a stratum of pure ice (not frozen soil) of unknown depth. This formation extends, with occasional gaps, north to Point Barrow, and thence east to Return Reef, where the ice layer is about six feet above the level of the sea. It goes south at least as far as Icy Cape without any decided break, and is found in different localities as far south as Kotzebue Sound."

Mr. F. C. Schrader, who travelled along the Arctic Alaska coast from the mouth of Colville River to near Cape Lisburne in 1901 also dissents from the views expressed by Dall.[a] He says: "The observations made by the writer, while boating along the coast, lead to the inference that the ground ice is not of so widespread occurrence as the above quotation indicates. Between the Colville and Point Barrow the ice is possibly more or less continuous along the coast, but of its inland extension we have little evidence. Even along the coast it is not extensively exposed. Here long stretches of the low tundra country are apparently underlain by rock or earthy deposit."

"Of the localities at which the ice was observed, the most important are Cape Halkett and Cape Simpson, at each of which it seems to be practically continuous for a distance of several miles.

[a] Seventeenth Ann. Rept. U. S. Geol. Survey, 1896, p. 855.

[a] A Reconnaissance in Northern Alaska in 1901. U. S. Geol. Survey, 1904. Professional Paper No. 20, pp. 91-93.

Cape Halkett, one of the most prominent promontories along this part of the coast (pl. x, *D*), terminates in an ice cliff rising thirty feet above tide level, and is overlain by a foot or two of muck, which in turn is carpeted by a nap of moss and grass at the surface. Judging from the topography, the ice at this locality may extend inland several miles. Its thickness is not known, since its lower limit lies below tide level. As shown in the view, the cape is being rapidly cut back by wave action, which undermines the cliff at tide level until by its own weight the ice breaks off in large blocks and is ground up by the surf.

"Of the Kowak clay containing Pleistocene vertebrate remains, referred to by Doctor Dall in connection with the ground ice, but little was seen by the writer. Observation, however, has been sufficient to suggest that, if present along the coast between the Colville and Chipp (Ikpikpuk) River, they are not only far from continuous, but are probably of very limited occurrence. Along the northwest part of the coast, the only locality at which what seems with certainty to be the Kowak clay was observed, is at Woody Inlet, about fifty miles southwest of Point Barrow. As this inlet is not far from the seventy-first degree of north latitude it is thought that the deposit may be near that in which Captain Beechey's party obtained elephant remains."

4. PRESENT DRAINAGE FLOOD-PLAIN ICE

All the rivers of Alaska present along their valleys two distinct classes of unconsolidated deposits. One consists of the low banks, which are only ten to twenty feet above the river and which are composed of fine dark alluvium alternating with layers of vegetable matter. Here buried logs and the upright stumps and trunks of trees are frequent, while their surfaces have often a covering of fresh mud, deposited by the spring floods. Lenticular masses of ice are frequently exposed in the banks of these flood-plain alluviums. The other class are the older deposits of higher and lighter colored silts without vegetable matter, which are cut by the rivers more rarely. These vary from fifty to two hundred feet in height.

The newer flood-plain ice occurs unconformably with alluvium and humus. Russell[44] amplifies on the formation of "Stratified Ice in the Tundra" as follows:

"The great number of lakelets on the surface of the tundra ren-

[44] Notes on the Surface Geology of Alaska. Bull. Geol. Soc. Am., Vol. I, 1890, p. 128.

ders it evident that if their extinction and the consequent burial of ice beneath the surface takes place in the manner supposed, sheets of ice, probably more or less lenticular in shape, should form a characteristic feature of tundra deposits. The origin of the lakelets may perhaps be due to the accumulation of snow banks on the tundra which by their late melting enable the moss surrounding them to grow more rapidly than on the more deeply covered areas. In this way a depression in the surface would be formed which would be flooded after the snow melted. A lakelet once started would perpetuate itself from year to year until the growth of moss from the sides led to its burial. An origin of this nature seems probable, as the lake basins (*in the tundra of flood-plains*) are due entirely to variations in the surface growth of vegetation and not to irregularities of the substratum of rock or clay on which the humus layer of the tundra rests. The origin and extinction of lakelets is thus a part of the normal growth of the frozen moss-covered plains."

Thus it appears the lower level and higher level forms of ice differ in that the presence of the newer is due largely "to variations in the surface growth of the vegetation," while the presence of the older elevated form is due to inequalities caused by slight deformations of the impervious clay deposits of the Pleistocene lake basins.

One phase of the occurrence of ice sheets in flood-plain alluviums which is of wide distribution and much interest is described by J. B. Tyrrell* in an article entitled "Crystosphenes or Buried Sheets of Ice in the Tundra of Northern America." As he describes the mode of occurrence of the ice under circumstances where it is most often encountered and observed—the placer mining districts of the region—the following is quoted:

"The Klondike gold-bearing district, to which my observations have lately been confined, and in which the deductions here set down were drawn, is a part of a great unglaciated belt or tract of country lying near the middle of the Yukon Territory in Canada, between the glaciated region which extends on both sides of the 'Chilcat' or Coast Range of mountains to the south and southwest, and the also glaciated region of the Ogilvie or Rocky Mountain range to the north and northeast. It is a country of high, well-rounded hills and deep, though flaring, valleys, in the bottoms of which flow streams with regularly decreasing grades. On one or both sides of these streams are everywhere deposits of alluvial material, varying from ten to a hundred feet in depth, consisting below of coarse sand

*Jour. of Geol., Vol. XII, p. 232, 1904.

and gravel, above which are fine sands with peaty and vegetable material, the uppermost layer, locally known as 'muck,' usually consisting almost exclusively of sphagnum swamp. The streams flow on beds of the coarser alluvial gravel or sand, seldom touching the underlying rocky floor, and are at present confined in relatively shallow channels, the sides of which consist of the peaty and finer alluvial material. Ponds or lakes are conspicuously absent.

"The surface of the whole country, whether composed of 'muck,' gravel, or rock in place, is almost everywhere permanently frozen, and while as yet comparatively few shafts have been sunk through this frozen layer, the evidence at hand would seem to show that it has a thickness varying from forty or fifty feet on the higher, uncovered parts of the hills, to two hundred feet in the moss-covered bottoms of the valleys. Here and there, however, there are unfrozen channels in the otherwise frozen layer, through which springs issue from the sides of the hills, carrying water from the deeper saturated, and unfrozen ground through the frozen layer to the surface."

On page 234 Tyrrell proposes the name "crystosphene" (ice wedge) for the underground masses of clear ice found in the Klondike country, and "crystocrene" (ice fountain) for the surface masses of ice formed each winter by the overflow of springs and that melt away each summer.

"Crystosphenes are formed by springs which issue from the rock under the alluvial deposits that cover the bottoms of the valleys. As a rule, they occur as more or less horizontal sheets of clear ice, from six inches to three feet or more in thickness, lying between layers of 'muck' or fine alluvium, usually where the 'muck' is divided horizontally by a thin bed of silt or sand; and most of them, as far as my observation goes, are from two to four feet below the surface, though some are deeper. In area they differ greatly. Those in the bottom lands of the gold-bearing creeks of the Klondike district vary in length from a hundred to a thousand feet, and in width from fifty to one or two hundred feet, as shown by shafts sunk through them at various places."

"Speaking generally, these ice sheets are of very even and regular thickness throughout, though they are not strictly horizontal, but approximate closely to the slope of the surface under which they lie. For instance, the city of Dawson is built on an alluvial bottom land declining gently from the base of a steep hill to the banks of the Yukon and Klondike rivers, and a crystosphene which here underlies the surface at a few feet beneath it seems to have about

the same slope. In another case a crystosphene was encountered on a mining claim three feet below the surface, and it was traced for five or six hundred feet down the valley, being everywhere at practically the same depth, while the surface itself had a slope of about one in a hundred, so that this apparently level sheet of clear ice was five or six feet higher at its upper end than at its lower. Examples of this kind could be multiplied almost indefinitely, showing plainly that these ice sheets do not partake of the character and attitude of frozen ponds or lakes.

"While these crystosphenes, or so-called 'glaciers,' are usually of the nature of nearly horizontal sheets, occasionally they occur as veins or dikes of ice rising through the bed rock into the overlying gravel. . . . . More or less vertical masses of ice are also sometimes met with in the gravels themselves, indicating the positions of former water channels from the bed rock toward the surface."

"In the majority of cases crystosphenes are in the vicinity of springs that can be plainly seen issuing from the bases of the neighboring hills, but in other cases no such springs are apparent. In these latter cases, however, wherever the gravel has been removed, and the underlying rock has been exposed, springs have been found."

"The mode of formation of these underground sheets of ice is therefore somewhat as follows:

"Water, issuing from the rock beneath a layer of alluvial material, rises through the alluvium, and in summer spreads out on the surface, tending to keep it constantly wet over a considerable area. In winter if the flow of water is large, and the surface consists of incoherent gravel, the water will still rise to the surface, and there form a mound of ice. If, on the contrary, the flow from the spring is not large, and the ground is covered with a coherent mass of vegetable material, such as is formed by a sphagnum bog, the spring water, already at a temperature of 32° F., rises until it comes within the influence of the low temperature of the atmosphere above, and freezes. This process goes on, the ice continuing to form downward as the cold of the winter increases, until, a few feet below the surface, but still within the influence of the low external temperature, a plane of weakness is reached in the stratified and frozen vegetable or alluvial deposit, such planes of weakness being generally determined by the presence of thin bands of silt or fine sand.

"As any outlet to the top is now permanently blocked, the water is forced along this plane of weakness, and there freezes; and thus the horizontal extension of the sheet of ice is begun. While thus increasing in extent, the ice also increases in thickness by additions

from beneath, until it has attained a sufficient thickness so that its bottom plane is beyond the reach of the low atmospheric temperature above; after which it continues to increase in extent, but not in thickness or depth.

"With the advent of the warm weather of summer the growth of the crystosphene ceases, but the cold spring water which continues to rise up beneath it has very little power to melt it, and its covering of moss or muck, being an excellent non-conductor of heat, protects it from the sun and wind, and prevents it from thawing and disappearing. Thus at the advent of another winter it is ready for still greater growth."

Ice sheets in alluvium bottoms on gradients appear to bear a certain relation to the isothermal surface marking the plane of division between the constantly frozen substratum and the annually thawed superstratum or surface layer. This thawed surface layer, composed in most cases of peat and growing sphagnum, or tundra (" Cryptogamic plants make more than nine-tenths of its mass, and on their power to grow above as they die and decay below depends the existence of the tundra.") lies like a tenacious wet blanket over the stable frozen substratum of alluvium or bed rock as the case may be. This blanket-like surface layer even where developed only to the extent of an acre or so is conducive to a condition of capillary saturation and hydrostatic semi-flotation. For in these Arctic regions the cold of winter penetrates into the saturated earth and converts it annually into a solidly frozen mass. However warm the short summers may be it is insufficient to melt more than a superficial portion of this boreal blanket, so only a swampy carpet of moss may flourish upon the constantly frozen substratum. Through this the standing water cannot sink. As the weather is never warm enough to carry it off by evaporation, these marshes extend far and wide, even up the sides of the hills and mountains.

An hypothesis to explain the occurrence of ice sheets under a mantle of moss under some of the circumstances where it is met with, especially on sloping surfaces such as Tyrrell describes for the Klondike region and which are common elsewhere in Alaska, is similar to a suggestion made by Lieutenant Belcher.[46]

The water sinks through the moss blanket from the surface and also seeps underneath it from higher levels. This tends to lift the living moss with its thawed underlying layer of vegetable humus or

[46] Beechey's Voyage to the Pacific and Beering's Strait, Vol. I, pt. II, Appendix, p. 600.

Photo. by Prindle.

View downstream on the Goodpaster River showing the annual flood-plain deposit of ice.

peat, floating it in a state of semi-buoyancy above the frozen substratum of alluvium or peat so the ice may accumulate season after season, as long as there is a growing and buoyant equilibrium maintained between the annually thawed peaty superstratum and the constantly frozen substratum.

The condition of semi-buoyancy or flotation frequently exists in bogs in temperate latitudes where the cold of winter is not sufficient to freeze the water underneath the peat, or at least where the annual result of such freezing they may be subjected to does not permit of ice surviving from year to year in whole or in part as it does in higher latitudes.

The Solway Moss in Cumberland, England, is a familiar historical instance of a semi-buoyant bog without ice underneath. It is of tradition that at the defeat of the Scots in this locality by the English in 1542, a troop of horsemen heavily mounted and heavily armored was put to rout. In the panic of their flight they ran headlong into this peat bog and became engulfed. More than two hundred years later, at the end of the eighteenth century, it is recorded that a digger of peat came upon a man and his horse supposed to be one of this troop, for both were in complete armor and preserved from total decay by the antiseptic qualities of the peat. In 1771 this bog, surcharged with the water of heavy rains, rose, swelled, burst, and swept over houses and trees in its course. It is easy to see how bogs similar to this might, if subjected to a climate as severe as that now prevailing in the Arctic regions, exist as an icy mass.[47]

The tundra mantle that covers practically all of this northern region, with the conditions it imposes upon the drainage of the country together with its properties as an insulating material are important if not the chief factors in the formation and preservation of ice. In considering its total and generalized effects there are presented a variety of conditions and probabilities upon which there is no data. Some of them are: the continuous summer heat and its total thermal effect, absorption, radiation, etc. The heat involved in the growing of the cryptogams that make up the large bulk of the tundra, and whether the effects are appreciable. Spontaneous combustion of peat, chemical decomposition of vegetable matter generating gases and heat and what effect these may produce in floating bogs and the ice they protect from disintegration.

[47] See interesting notes about bogs in "Facts About Peat," T. H. Leavitt, Boston, 1867. Third edition.

The views of the flood plains of the Goodpaster River, presented in plates v and vi, show the annual deposit of ice formed by the freezing of overflow water and snowdrifts saturated by the same. Deposits of this kind are spoken of as "*annual glaciers.*" It is seldom that even remnants of them survive from one year to the next. As a rule such accumulations entirely disappear each summer to form again the following winter. This is a transitory form of flood-plain ice and belong to the same class as river ice, for it has a similar mode of formation. The persistence of this form of ice through the summer is due simply to the fact that the spring freshets are too feeble to disintegrate such winter accumulations on the smaller streams as do the floods of the larger rivers.

Mr. A. J. Collier has observed underground drifts made during mining operations fill with water by infiltration and freeze in the course of one winter so the workings are completely blocked. E. S. Balch, in a work entitled, "Glacières or Freezing Caverns," Philadelphia, 1900, gives data on the causes of subterranean ice, pages 109-161, and on page 115, speaking of ice sheets says: "In northeastern Siberia, a form of permanent surface ice is found, which the Tungusses speak of as *tarinnen,* which means 'ice troughs' or 'ice valleys.'[48] These tarinnen are broad valleys, with either a horizontal floor or one sloping gently in the form of a trough, over which the ice is spread in the form of a sheet. The Tungusses assert that the ice in some of these troughs never wholly melts away, although it lessens in quantity from the beginning of May till the end of August, after which it once more increases." On pages 166 and 167 Balch mentions the "Subsoil Ice in Alaska,"[49] citing I. C. Russell, and "Subsoil Ice in the Klondike Region,"[50] "Ice Cliffs on the Kowak River, Alaska,"[51] and "Subterranean Ice Sheet on Kotzebue Sound."[52]

5. SNOW-DRIFT ICE

The only ice whose origin can be wholly and positively assigned to drifts of *wind blown* snow are the accumulations found under sea cliffs and other escarpments, in cañons, gullies, and ravines.

[48] Bulletin de la classe physico-mathematique de l'Academie Imperiale des Sciences de St. Petersbourg, 1853, Vol. XI, pp. 305-316.

[49] A Journey up the Yukon River, p. 149, and Second Expedition to Mount Saint Elias, p. 19.

[50] Philadelphia Ledger, December 30, 1897.

[51] Lieut. J. C. Cantwell, National Geog. Magazine, October, 1896.

[52] Otto von Kotzebue, Entdeckungsreise in die Südsee, etc. Weimar, 1821, Vol. IV, p. 140.

Photo. by Hess.

Panorama of the valley of the Goodpaster River looking north, showing accumulations of winter overflow flood-plain snow ice.

Their general character is shown in fig. 1, plate VII. This sketch from Captain Beechey's Narrative of the Voyage of the Blossom illustrates a deposit of snowdrift ice as typically developed on the Arctic coasts. They are of an entirely recent and transitory nature, not to be confused with beds of ice in any way. They lie banked solidly against the escarpments at intervals along the Arctic coast and sometimes along the larger rivers. Sometimes they persist for a number of years, but all are eventually undermined by the waves or undercutting of the banks against which they hang and disappear to be repeated elsewhere under more favorable conditions.

Sir John Richardson[64] remarks: "Elsewhere on the coast, cliffs equally vertical, but having a different exposure, were seen masked by a talus of snow, over which a coating of soil had been thrown by land floods of melting snow pouring down from the inland slopes. The duration of these glacier-like snow banks varies with circumstances. When the cliffs rise out of deep water, the ice on which the *talus* rests is broken up almost every summer, and the superincumbent mass, previously consolidated by the percolation and freezing of water, floats away in form of an iceberg. In other situations the snow cliffs remain for a series of years, with occasional augmentations marked by corresponding dirt bands, and disappear only towards the close of a cycle of warm summers. In valleys having a northern exposure and sheltered by high hills from the sun's rays, the age of the snow may be very considerable; but it is proper to say that though aged glaciers of this description do exist on the shores of Spitzbergen and Greenland, they are of very rare occurrence indeed on the continental coast of America."

Such snowdrift ice deposits also form in cañons, gullies, and ravines, but most generally are carried away each summer. They occur at all levels from present river banks and bottoms to places favoring their formation high upon mountain sides. The writer has seen occurrences of snow ice of drift origin banked solidly against the escarpment faces of the old dead elevated ice beds where it was intimately associated and almost incorporated with the face of the older ice.

One who has not seen its mode of occurrence, examining samples from it in the laboratory, upon classifying the ice merely upon its physical appearances and comparing such results with those of other experiments not having the same bearing, might assert that it possessed all the characters of drift snow ice as to air and dirt content,

[64] Zoology of the Voyage of the Herald, 1854, p. 6.

and contend, on the basis of these variable facts, that the bed of ice it may be confused with is also a deposit of snow drift origin.

6. LAND ICE IN SIBERIA

The real significance of land ice in Siberia with explanations to account for its origin appear to be as confused as the opinions concerning analogous phenomena in Alaska.

According to Toll's opinion[54] the ground ice deposits are nothing else than fossil glaciers, but he admits for certain cases the same origin Tolmatschow[55] accepts for the Beresowka ice. "If we observe," Toll says,[56] "the map, we see that masses of *stone ice* apparently of the type of a fossil glacier are to be found at the mouths of rivers. And if admitted, as I shall show later on, that the islands of New Siberia and the continent were still united in the Quaternary period it will be easy to reconstruct the courses of the rivers between the islands and the continent. In this case it may be thought that the masses of snow ice belong to the river terraces. i. e., that they are the remains of snow fallen during the winter, which have been covered by the spring overflow of the rivers and then fossilized. I admit that some isolated cases like this do happen. But observation of the conditions I have learned to know, as on the Ljachow islands, will hardly permit me to think that such an exceptional formation has given rise to those imposing accumulations and others like them."

The observations of Toll, who reported having seen on the southern coast of Ljachow Island an uninterrupted sheet of ice, with an earth layer on it, nearly ten versts long, have been criticised by Bunge.[57] Bunge thinks that when Toll visited the island the whole coast was covered with deep snow, and this snow has been taken by Toll to be an ice sheet. Toll was there in the spring. Bunge in the summer.

Toll supposes such deposits of ice represent the remains of glaciers, basing such contention primarily upon its physical characteristics, that it can only be snow ice, and resembles white glacier ice, or even névé, because rich in air. Tolmatschow supports Toll as far as favoring the view that the deposits are of snow origin:

[54] Die fossilien Eislager und ihre Beziehungen zu den Mammuthleichen. Mem. d. l'Acad. Imp. d. Sci., VII Ser., T. XLII, No. 13.

[55] Bodeneis vom Fluss Beresowka. Verhandl. d. K. Min. Geo., 2 Ser., Bd. XL, pp. 415-452.

[56] Op. cit., p. 79.

[57] Einige Worte zur Bodeneisfrage. Verh. d. R. K. Min. Geo., St. Pb., II Ser., Bd. 40, p. 205.

From plate in Beechey's Narrative.

1. Cape Smyth, Arctic Coast of Alaska, showing a deposit of snowdrift ice.

2. Reproduction of Kotzebue's Plate illustrating the Ice Formation on Eschscholtz Bay.

"Dr. Bunge, who was with Toll on the New Siberia Islands, studied the ground ice formation carefully, but he came, in explaining the origin of the same formation, to conclusions quite different from those of his companion. According to Bunge's opinion the ground ice is a vein or strata-like formation: 'The contraction of the tundra ground caused by the cold, has given rise to many crevasses, which must have been large and deep. In spring and summer a heavy rainfall, coming in contact, in those crevasses, with frozen earth, freezes. This goes on a long time, sometimes many years, and in this way large veins of ice are formed in the tundra ground. The water not frozen can expand horizontally and so form horizontal sheets of ice. Through the wasting away of the tundra by the sea or a river the vein of ice may be laid bare and so expose an ice wall.'"

Tolmatschow comments: "It may be remarked the formation of the ice in such a way cannot be deduced from its structure. Water forming from snow is very rich in air, but from it ice so rich in air as snow ice cannot form. It is possible that, from the water that first comes into contact with the frozen soil, a thin sheet of ice comparatively rich in air, might be formed. But when the direct action of the very cold ground on the flowing water is excluded by this sheet of ice, we have conditions very similar to those which lead to the formation of the so-called blue ice of the present time glaciers. The color and name of this (blue) ice comes from the very small number of air-bubbles or from their complete absence, though the water coming from the melting of the surface of the glacier is by no means so poor in air as that of the tundra." Bunge says explicitly that the ice he has seen "has always small cracks and bubbles." Toll also points to the richness of the ice in air bubbles, and this proves once more that the land ice comes from snow. (Toll also gives photographs showing the granular appearance of the surface of the ice upon melting to support the contention of its snow origin.) If two learned men collect a large amount of data in the same district from the same formations in order to solve one question, and afterwards come to two conclusions contradicting and excluding each other, we must say that the question is not clear, even as it appears on the spot, and more close observation is to be desired. There is no doubt that vein ice is much spread in the tundra, but according to the structure of the ground ice, as it has been described by Bunge and Toll, it cannot have come from water, but from snow. "It seems to me (Tolmatschow) that some of the examples given by Bunge correspond exactly to this (snow) way of formation."

"In the case of the Beresowka the supposition of Bunge is untenable. The ice wall there presents a concavity of great radius, corresponding to the curvature of the bank of the river, i. e., to the direction of the washing away by the Beresowka, but not of a crevasse. Neither can his supposition explain how the ice is to be found at the upper edge of the terrace.

"The presence of ice on a terrace gives us an occasion to say a few words about the supposition accepted by many American scientists about the formation of land ice from lakes. We can very well imagine such a way of formation of the ice and accept it for certain cases, but then the ice must have the structure of water ice, and this is not the case with the Beresowka ice."

As will be discussed later the classification of ice by its gas content presents a very wide range of possibilities, for in nature many extraneous conditions must be considered that do not present themselves in laboratory examinations. Apparently nothing is to be gained toward demonstrating the snow origin of ice-beds by a microscopic study of its crystalline structure, for the ice no matter of what origin, but especially if from water, may undergo such modifications in crystalline form by recrystallization and regelation, especially near exposed surfaces, as to obscure all tracing of its original structure or origin. The presence of air or gas bubbles of various shapes and in varying quantity to the cubic unit of ice lead to nothing upon which to base even conjectures, for this phenomenon of enclosed gas is a variable occurrence in both snow and water ice, especially in nature.

"According to Toll's observations of 'stone ice' in the islands of New Siberia there is not any stratification to be found.[88] In other cases, as for instance in the ice deposits of the Ljachow Island, and also in quite new ice exposures on the Siberian continent on the lower Yana, he saw the stratification quite distinctly. When Bunge speaks of the ground ice of northern Siberia, he says explicitly: 'if the mass of ice were stratified, we should consider it as coming from accumulated masses of snow. These, of course, would have shown horizontal stratification, similar to those that we find in new deposits of snow; but nowhere are horizontal stripes to be found.'

"We must therefore admit that this ice is really not stratified, for it is not possible to admit that the stratification has been overlooked by the observers."

[88] Die fossilien Eislager, p. 72.

Tolmatschow's Views on the Ice of the Beresowka River

An abridged translation from the report (in Russian) of O. F. Herz, chief of an expedition sent out by the St. Petersburg Academy of Sciences to investigate the finding and excavating of remains of a mammoth, partly in the flesh, in a frozen state, on the banks of the Beresowka River, a tributary of the Kolyma, in northeastern Siberia, is published in the Smithsonian Report for 1903, pp. 611-625, pls. I-IX. Herz gathered some pieces of ice, along with other specimens from the formations associated with the mammoth. These materials were taken back to St. Petersburg, where he placed them together with his field notes and sketches in the hands of I. P. Tolmatschow to report upon from a geological standpoint.[20]

These accounts of Herz and Tolmatschow are of particular interest because they throw much light on the circumstances surrounding the occurrence of such remains. Unfortunately the position in which the carcass was found, was secondary to its place of original interment, and leaves doubt about one important point—whether the mammoth died and became entombed before or after the thick bed of ice, forming the terrace feature along the bank of the river at this place, was formed; or while it was forming. There appears to be no evidence at hand to settle this question and place the time at which this particular animal died and thus give us an authentic record of the occurrence of the mammoth in its true geological (stratigraphical) horizon.

Tolmatschow says: "The difficult task of the expedition, i. e., the taking of the mammoth carcass to St. Petersburg in the best possible condition, the short time at its disposal, and the cold winter with much snow, did not permit of the pursuit of geological researches as completely as would have been desirable. Besides this the chief of the expedition, O. F. Herz, is not a geologist, but an old zoologist, and was not at all prepared to make geological observations because there was a geologist, Herr Sevastianoff, among the members of the expedition. (For some unstated reason this member did not accompany Herz to the mammoth remains on the Beresowka, but after reaching Mysova, within eighty-five miles of the mammoth, returned to Sredne-Kolymsk.) "

Tolmatschow devotes most of his article to a discussion of the properties of ice as a mineral, its crystallographic forms and the

[20] Bodeneis vom Fluss Beresowka. Verhandl. d. K. Min. Geo., 2d Ser., Bd. XL, pp. 415-452, pl. V-VIII.

varying amount of gas or air content in different kinds of ice, for he considers ice the most important geological feature of the place where the mammoth was found. He made a microscopical examination of the ice from the Beresowka River and considered the specimens of rock and soil only in order to understand the way of formation of the layers of clay, loam, and Quaternary detritus of the district.

"The samples of ice from the Beresowka were taken by Herz from two different places. Two small pieces (*A*) come from a little ditch excavated under the mammoth, 1.9 meters deep; the third piece, a larger one, (*B*) was taken from the lower part of the ice wall which is situated on the upper edge of the terrace on the bank of the river 55 meters above its level. As the two kinds of samples show some differences in their properties they are described separately.

"*A*. Comparatively pure transparent ice of a yellow color, a little dirty with a great quantity of cylindrical or oval bubbles of air (more properly of gas) disposed in parallel lines in a very regular way.[*] The bubbles are 1.5 mm. broad and 3-5-6 mm. long. The clayish parts which make the ice dirty, sometimes form layers as thin as paper. The action of heat breaks the ice into an agglomeration of rounded-off polyhedral grains from 5 to 7 mm. in diameter. The same grains, or better speaking their sections, are obtained at the surface of the ice, if it is rubbed on a hot plate of iron. Under the microscope we see in these specimens (especially when obliquely illuminated) thin scratches at the extremities of the single grains, and between crossed Nicols we notice also, that each grain is an independent crystal of ice, which lies amongst other crystals without any common crystallographic orientation. When one grain appears colored, the next remains dark when the specimen is turned, and under convergent light we see the cross of a mineral with one axis. . . . .

"By endo-metrical calculation I have found that one kilo of ice contains 180 cu. cm. of air. . . . . When the ice melts a small quantity of clay is obtained, which has been highly calcined and weighed. One kilo of ice contains up to 3 grams of clay, i. e., 0.3%. The specific weight is calculated 0.795.

"*B*. This ice is apparently dirtier than the first (*A*) probably because the particles of clay do not form as in (*A*) thin layers, but instead are uniformly distributed within the whole piece. The

[*] Op. cit. pl. v. f. 1.

bubbles of air are not so many, they are round or egg-shaped, and they are irregularly distributed. Upon melting, this ice also divides into rounded polyhedral grains of an average diameter of 5 mm., and altogether they are smaller than those of the first samples (*A*). Under the microscope we see the same images as before. The air contained was 50 cu. cm. per kilo of ice, the remains of clay 0.24%, i. e., 2.5 grams per kilo. The specific weight was 0.878.

"The first conclusion we may arrive at from these observations is that the ice just described cannot have been formed directly from water. Ice coming from the surface of water, for instance from a pond, shows a parallel increase of long-stalked crystals, whose optical axes are perpendicular to the freezing surface. A section taken from such ice shows under the microscope all the properties of a crystal. When melting, such ice divides into a series of irregular prisms some decimeters long. . . . . The freezing of water is much more complex than might appear when we observe an already formed piece of ice. But this relates only to the first phase of the formation of ice. Later on the freezing goes on in a much simpler and more regular way, so an ice is formed which in its principal mass is characterized by its prismatic structure and thereby can be easily distinguished from snow ice, as has been known for a long time, and recently once more clearly shown by Prof. E. Drygalski [a] in his study of the materials of the Greenland expedition. The large quantity of air of the ice coming from the Beresowka differentiates it also from ice coming from ordinary freezing of water, and confirms its snowy nature, as is shown by the great number of observations carried on chiefly on ice of glaciers.

"The well-known works of Agassiz and Nicolet have shown that one kilo of snow on changing into névé contains 64 cu. cm. of air; one kilo of white glacier ice 15 cu. cm. and one kilo of blue ice 1 cu. cm. . . . .

"It is easy to see that the quantity of air contained in the ice of the Beresowka approaches that of white glacier ice and even to névé ice, especially for the first sample (*A*).

"Its structure, which we have described above, resembles that of glacier ice, though in comparison to the ice of the Alpine glaciers, the grains are very minute. But in comparing it with the ice of the interior of Greenland, we do not notice this difference so much."

"The characteristic structure of névé ice—a conglomerate of ice grains kept together by an ice cement formed of very small grains—

[a] Grönland-Expedition, B. I, XVIII Kapitel. Die Structur des Eises.

has completely disappeared from the samples we have described. Herz does not say anything about the sheets of the principle mass of ice, he mentions only thin sheets of ice which appear in the layer of earth which covers the main body of ice. We can therefore say that the division of the main ice mass into layers either does not exist at all, or has been obscured by the secondary process of melting and erosion, and this last is the most likely thing to have happened."

The writer cannot agree that "the secondary process of melting" has obscured any stratified appearance of the principal ice mass on the Beresowka. Herz more probably failed to note such structure because it did not exist. However, he suggests that a more or less secondary and superficial process of melting partly accounts for the ice with large gas content such as Tolmatschow's samples exhibit and also for its granular structure. Granting all the theoretical considerations of ice Tolmatschow asks for, and granting without hesitation that his samples are snow ice, we are no nearer an explanation of the true origin of the fundamental bed of ice on the Beresowka. The characters of his samples fail to prove that the bed of ice in the terrace of the Beresowka has an origin from consolidated beds of drifted snow.

There appears to be two distinct kinds of ice associated with the mammoth on the bank of the Berĕsowka. One of fundamental, the other of superficial position and arrangement; one of stable and the other of transitory aspect. The writer considers the samples gathered by Herz and examined by Tolmatschow were from that kind of ice which is superficial in position and more or less transitory in its origin and occurrence; that therefore it is of no weight whatever in demonstrating that the fundamental ice feature of the Beresowka is of snow origin.

To explain: Tolmatschow's samples (*A*), two small pieces, came from a little ditch excavated under the mammoth 1.9 meters deep; (*B*) a large piece came from the lower part of the ice wall which is situated on the upper edge of the terrace on the bank of the river 55 meters above its level.

In brief, samples (*A*) came from the sliding talus slope and may well be of snow origin as the winter snows accumulate, pack down in crevices, and together with thaw water percolating through the interstices of the frozen talus blocks, become consolidated into ice. This appears to account for all the ice immediately associated with the mammoth's carcass as described and figured by Tolmatschow.

Sample (*B*) may also be of snow origin for snow accumulates

and solidifies against ice escarpments as readily as elsewhere. Tolmatschow's results and conclusions in regard to the ice of sample (*B*) may have been different if the sample had come from higher up on the ice face, or better still, if it had been taken more from the interior of the mass. As it is, the sample coming from the *lower part* of the *surface* may, even if not admitted to be of snow origin, readily have been modified "*by the secondary process of melting and erosion*" of water ice and must be admitted to be of a superficial nature and not a criterion by which to judge the origin of the mass of the ice bed.

It must also be borne in mind that those who think some ice deposits are of water origin, i. e., are frozen from water and not

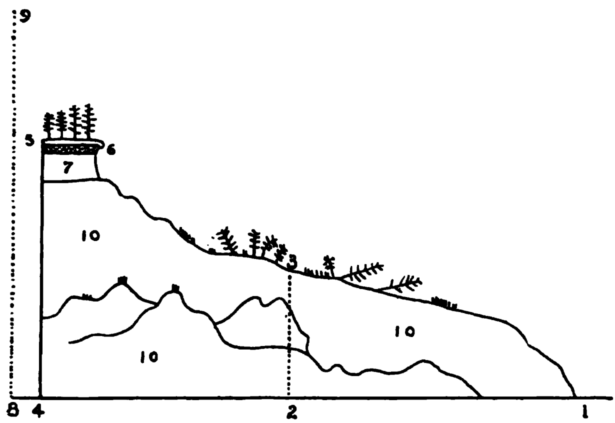


FIGURE 1.—Section of the bank of the Beresowka River with gliding talus at the place where the mammoth carcass was found.
[After Tolmatschow, op. cit., fig. 4, p. 430.]

1-2-4. Water level of the Beresowka.
2-3. 35 meters.
3. Place where carcass was found.
4-5. 55 meters.
5. Layer of soil.
6. Alluvial layer with shingle and lamellar ice.
7. Ice bed (fundamental position).
8-9. 120 meters, height of porphyry ridge ¼ mile back of terrace.
10. Pleistocene silts (lacustrine).

snow, do not claim that the process by which it transpires is the same as that of the freezing of an open, unobstructed expanse, like a lake or pond, that when once frozen it is suddenly covered over its whole area and preserved so that the normal crystallographic structure of the ice will be retained. The process is far different from this. True the pond or lake freezes over every winter, but

only such parts of the ice around the margins are preserved through each year as become protected by the mantle of moss whose growth gradually encroaches over the water from the shore margins each season. Where the lakes on the tundra have grown comparatively small and shallow, we almost invariably find on and near their banks a layer of semi-buoyant turf or peat under which in many places ice persists the year round. In this way conditions are presented that permit of the water acquiring a considerable gas content and also considerable dirt from decomposing vegetable matter, for quantities of vegetable organisms (diatoms) accumulate on the bottoms of even these Arctic ponds and lakelets there to decompose and evolve gases that may form bubble cavities in ice. By partial thawing and freezing such ice may also undergo rearrangements of its crystallographic structure as do salt and borax occurring in beds.

Before classifying ice as of snow or water origin upon the percentage of air it contains there is to be considered the phenomenon called anchor, frazil, or specular ice, forming when temperatures are very low. For instance, when the wind blows cold over a lake surface, the temperature of the upper two, three or more feet is reduced considerably below the freezing point and is colder than a surface sheet of *still water* when ice begins to form. In the former case the water is full of ice needles to a considerable depth and forms a granular ice very different from that in the latter case, when the needles congregate in a horizontal plane at the surface.

Features of the Beresowka Locality

"There are two very characteristic points about the Beresowka, one of the large affluents of the Kolyma, (1) its large valley and (2) a very winding course. This is particularly true of the part where the mammoth has been found; of this part Herz sketched a plan on the scale of 1 : 84,000.

"The remains of the mammoth lay on the left bank of the Beresowka which is being more and more washed away by the river. The Beresowka makes here a great winding by which a low alluvial peninsula (an island when the water is high) is formed, covered with willows and other shrubs. On the left of the Beresowka there is a steep bank 55 meters high above the water, then there is a terrace half a kilometer (about ¼ mile) wide extending for several kilometers (about 3 miles) along the river. The terrace is limited by a mountain range 120 meters high, which is separated from a second range 180 meters high by a small depression

of the surface. The formation of the bank is well shown by Herz's photographs. He did not go to the opposite side of the valley but noticed there, as on the left side, a 'Taiga' (wooded terrace) which runs along the river as a broad strip of land, and which he distinguishes from the lowlands or bottoms of the newest alluvial deposits of the Beresowka.

"From this point, up and down, the valley of the Beresowka becomes narrower, the mountains east and west get nearer to each other and they bound a large expansion of the valley similar to a

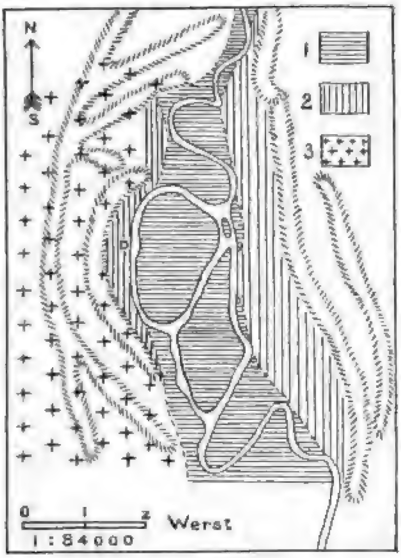


FIGURE 2.—Geologic map of the Beresowka valley about place where the mammoth was found. Small square indicates the position the carcass was in. [After Tolmatschow, op. cit., fig. 1, p. 425.]

1. Recent alluvial deposits of the Beresowka.
2. Older terrace deposits "Taiga."
3. Porphyry of nearby hills.

lake. The older formation of the left terrace is what remains of a deposit that once filled the whole lake-like expanse of the valley of the Beresowka. According to Herz's opinion the deposits of the left bank originally filled the whole valley, but have been swept away by the Beresowka, so that only small portions remain and these will soon disappear. Although the right side of the valley was not examined its 'Taiga' terrace corresponds, orographically, to the left terrace.

"Now to consider the geological structure of the terrace more closely. (1) Above is to be found an earthy layer, covered with moss, 30-52 centimeters (12-20 inches) thick. (2) Under this a layer from 2-4 meters thick composed of layers of clay with coarse shingle corresponding, petrographically, to the rocks of the nearby mountains. With the shingle in this layer was also found pieces of wood, bones, etc. Through this clayey and loamy deposit besides the stones, roots, and pieces of wood, were lamellar layers of ice up to 15-18 centimeters thick, stretching through the mass. (3) Underneath this alluvial layer there is a vertical wall of ice five and even seven meters thick. With this ice wall the section closes, because below it comes the sliding talus to be found everywhere along the slope of the terrace. Under the place where the mammoth lay Herz dug to the depth of 2.25 meters. At first the excavation passed through deposits of earth alternating with thin layers of ice, but at a depth of 1.90 meters a compact mass of ice was found, which was not passed through at 2.25 meters depth."

Tolmatschow reviews the several suppositions that may be drawn about the thickness of the fundamental ice bed, for it appears in the Beresowka section the lower surface of this ice was hidden by talus. He does not think that it extends down to the level of the Beresowka as Herz thought,[a] and it is not represented that way in the profiles given, because in this case the structure of the bank would be quite different. . . . . Tolmatschow says: "The large dimensions of the sliding mass make me suppose that under the ice wall and high above the level of the Beresowka are to be found other deposits of clay and loam. The photographs (pl. VIII) and the sketches made by Herz give the sharp contrast between the vertical ice wall and the slope of the bank. If the thickness of the ice was greater there could not be such a contrast."

The writer can state that in apparently analogous cases observed in Alaska the ice rests on top of considerable thicknesses of homogeneous Pleistocene clays such as appear to form the body of the terrace on the Beresowka.

"By the washing away of these deposits the ice sheet above is undermined, the layers become loosened so that they fall and slide little by little with all that is to be found on them. Only in this way it seems to me, can be explained the singular fact that the mammoth, which lay in a sliding place, therefore in a secondary deposit, was found nevertheless in such a way, that there can be no doubt left about the place and position from which it has fallen."

[a] See translation, Smithsonian Rep., 1903, pp. 616, 618.

XI.—LAND ICE AND THE MAMMOTH

I. ASSOCIATION OF PLEISTOCENE MAMMAL REMAINS WITH ICE

The writer considers Tolmatschow's conclusions as to the horizon of the mammoth to be unestablished by the facts surrounding the finding of the Beresowka carcass, but beyond pointing out that it is not proved that this carcass came from above the ice bed there appear to be no suggestions to offer. Unfortunately there is every possible doubt about the true original position of this carcass, there being three horizons as far as position is concerned in which it may have been originally entombed. They are in descending order: (1) The clay and shingle layers intermingled with lamellar sheets of ice above; (2) the thicker, homogeneous and more fundamental (from a stratigraphic standpoint) ice-bed that forms the conspicuous part of the escarpment of the terrace wall; (3) from the Pleistocene clays underlying this thicker bed of ice.

As the writer's experience has been confined to Alaska, where as before stated no authentic instance of the occurrence of Pleistocene mammal remains is known in primary stratigraphic position, it is impossible to state whether the mammoth was confined to any particular one of the three horizons enumerated above or may not be found in all three of them.

Tolmatschow says: "As until now the bones and carcasses of mammoths have been found only in the earth layers on the ice, Toll thinks that the ice sheet represents a deposit stratigraphically independent from the upper one containing the bones of the mammoth. The Beresowka occurrence seems to confirm this supposition. But by the observations of Herz's expedition so many new things have been learned about the way mammoths lived, that we may imagine another reason for finding the mammoth in the earth layers on the ice.

"The remains of reeds and other grasses found in the mouth (partly on the tongue) and in the stomach of the mammoth show us, that at least in this case (and, it better be modified, at that particular moment), the animal was graminivorous, an inhabitant of the meadows, and these meadows were found by the animals on the river terraces, which in spring were likely to be under water and in summer, in spite of the layer of ice under them, were covered with a magnificent vegetation. In such meadows, perhaps where swampy, mammoths occasionally became engulfed and disappeared without having swallowed their food. It is likely such occurrences happened often on the terraces. Along with the animals fallen on

the spot, those floated down by the water during spring floods, were also buried in the terrace. Herz found under the mammoth carcass a distinct cervine antelope skull, which could have been brought there only by water. (It no doubt dropped from the alluvial layers above the thick ice, where fragments of bones were noted, and in this way became mixed in the talus.) Every place where the upper layers of earth are thick enough, i. e., where they have been forming long enough, fossil animal remains have been able to accumulate in large quantity. On the other hand where the alluvial layers are thin, such remains are rarely found, firstly, because they had not much attraction for living animals, and secondly, because bones carried there could be easily washed away.

"The finding of the mammoth in the earth layers, situated on the ice, is not a reason for considering the ice and earth layers as two geologically distinct strata and therefore belonging to different ages. Of course the upper layers of earth have been deposited after the formation of the ice, but the mammoth is a sure proof of the previous formation of the ice on which its carcass has been found. About this I will repeat the words of Tscherski.[a] Without entering into a discussion about the formation of the ice, and simply accepting the explanation of Toll, Tscherski in his works says: 'The old glacier which did not extend to the limits of the continent, but which in our opinion existed in the same region as the carcasses of the rhinoceros and mammoth, would not necessarily displace these coeval animals. Instead, the facts observed have persuaded us on the contrary, that these characteristic representatives of the Siberian post-pliocene fauna have not hesitated from treading, at the first occasion, on the mass of ice, which temporarily deprived them of part of their meadows.'"

Tolmatschow remarks: "As a consequence of what I have said I cannot consider the ice layers and a northern glacial transgression in the 'Yenissei Tundra' as having occurred at the same time. The only reasons for such a consideration are the 'marine clays with glacial detritus' in the Yenissei (delta) Tundra, the 'Stone ice' in the Anabara 'Tundra,' and the remains of mammoth in the earth layers of the New Siberia Islands. Above we have already discussed the relations between the ice and earth layers.

"We must not deny, of course, that the conditions, by which the ice age was brought about in the northern hemisphere, have passed

[a] Beschreibung der Sammlung posttertiärer Säugethiere. Mem. de l'Acad. Imp. Sc., St. Pb., VII Ser., T. XL, No. 1, p. 473.

away for Siberia, without any action, but there are only some local traces remaining. If the humidity of northern Siberia, which now has a very dry climate, were to increase slightly, the rainfall would certainly increase. It is quite possible that the formation of lake deposits of ice would occur during a period with heavy rainfall. But even if we call these older deposits of ice 'fossil ice' it does not follow that it is either the remains of a glacier or of continental ice, because, for such occurrence many different conditions and characteristic features are necessary, which are not yet known to exist in northern Siberia.

"As appears from the description of the Beresowka valley, deposits corresponding to the horizon of the mammoth are very common in this part of Siberia. All the older ground-ice deposits most likely belong to the same horizon."

In brief, Tolmatschow appears to be aware, without being conscious of the significance thereof, of the existence of an older ice on top of elevated Pleistocene silts. No doubt if he had viewed the phenomena personally he would have fully recognized this apparent fact.

Wrangell[64] says: "The best mammoth bones as well as the greatest number are found at a certain depth below the surface, usually in clay hills, more rarely in black earth. The more solid the clay, the better the bones are preserved. Experience has always shown that more are found in elevations situated near higher hills than along the low coast or on the flat tundra."

The one point that appears to be a matter of unanimous agreement among those who have described the Elephant Point locality on Kotzebue Sound, Alaska, is that the remains never occur in the ice-bed nor the peaty or earthy layers overlying it. It has been generally conceded they were derived from the clay beneath the ice. Hooper's suggestion is worthy of serious notice in accounting for some of the remains at Elephant Point. He says:[65] "Kotzebue was undobutedly in error in supposing that the fossil remains of animals found in the vicinity were embedded in the cliff, I examined them carefully each season and saw no signs of animal remains of any kind; while on the shore (beach) below high-water mark, we found them in abundance. They were not confined to the locality of the cliff, but extended each way as far as our investigations reached. They evidently came from the Buckland River, and were

[64] Wrangell's Voyages, p. 286, note.

[65] See Appendix.

brought down by drifting ice in the spring." Floating ice from the Buckland River also undoubtedly explains the presence on this beach of blocks of sandstone and basalt noticed by Beechey.[**]

The writer can attest to the transporting of bones considerable distances by rivers. In the summer of 1904 he ascended the Old Crow River, a tributary of the Porcupine, by its meandering course about one hundred and seventy miles, and along the upper one hundred miles of this distance found strong evidence in the shape of scattered bones of the former existence of mammoth, bison, and horse. On the bars also were accumulations of the broken and comminuted fragments of their bones. These remains were without exception all found below the high-water level of the flood stages of the river and were without question brought down from some primary source or sources of deposition, by the great transporting agent in those regions, floating ice. Yet the formation of the river banks along which the remains occur is a continuous deposit of Pleistocene lacustrine silts rising about 150 feet above the river level and frequently exposing, where the river is cutting laterally into them, terraced escarpments of ice. The ice deposits do not form a continuous sheet over the whole lacustrine area, nor do they rise as solid walls from the water level. They occur in the undulations of the surface on top of the silts as beds 10 to 30 feet thick, as already explained, and are elevated 100 feet or more above the river. In no case were individual beds of ice exposed for more than one mile and in most cases the exposures are not so extensive as this. In no case was anything seen above the ice but peat and humus. This is explained, however, by the fact that the deposits as exposed by the sections examined comprise the central area of what has been an extensive Pleistocene lake. Only near the former lake shores are to be expected the conditions of abruptly rising land slopes to afford detritus and alluvium for deposits on top of the ice such as exist at the Beresowka locality and at Elephant Point. It also appears from these cases that the surfaces of the drained lake bottoms where extensive were too treacherous or uninviting for the mammals of that time to wander out over them, so experience thus far points towards the immediate shores of the Pleistocene lakes as the places to search for mammal remains in their primary position.

In reviewing the facts as they appear the writer is satisfied that the statements to the effect that the ice-beds associated with the

[**] See Appendix.

mammoth are of snow origin or occur interstratified with the Pleistocene silts are based on misinterpretations of the facts as they exist. The erroneous conclusions drawn have passed down in literature and become so firmly fixed in the minds of some that it will no doubt take time to shake their belief. The evidence afforded by the exposures on Eschscholtz Bay is insufficient to support a claim that any of the ice-beds we know of in Alaska, excluding glaciers, are of Pleistocene age or existed before the mammoth became extinct.

The latest supporter of the snow-ice supposition—Tolmatschow—gives what he calls a "schematic representation" of the formation of the Beresowka ice from snow as follows: "The large lake through which the Beresowka flowed was filled with silt through which the river now cuts its bed. In winter the whole basin was covered with a thick bed of snow, which in summer disappeared except in those parts which are protected by a layer of loam. For the thinnest layer of such deposits, whether coming from the overflow of the river, or from the water melting from the mountains, affords a good protection from the summer sun. In our climate (Russia) the snow remains under such conditions up to the middle of summer, it will therefore remain more easily in northern Siberia. In certain cases the snow can remain until winter without any protection, i. e., when it accumulates in great quantities, and this can happen easily in such basins, where not only the fallen snow accumulates but also that blown from the nearby mountains. After short summers long winters come again and again.

"These beds increase, come into contact, melt together, and in a long series of years form a thick cover of snow. . . . For this explanation we need not make any supposition about oscillation of climate, the age of ice, etc., and we may very well suppose that the process is also going on in Siberia now.[a] There is no doubt, that under the present day conditions of the climate of northern Siberia ice as it has been found on the Beresowka can remain undisturbed for thousands of years if we only exclude the action of its being washed away by the river."

From his various suppositions about the formation of the Beresowka ice Tolmatschow draws the same conclusions as before, i. e.,

[a] One of the weak points of the snow origin of ice is just this: Why do we not find the process transpiring today? Also, why is the elevated ice only found associated with the Pleistocene lacustrine silts? Why not at varying levels, and resting upon surfaces of different geological formations, etc. The snow ice phenomena we do find today are altogether different from those ice deposits associated with the elevated Pleistocene silts.

that the deposits represent large accumulations of snow in the river valley, but not the remains of a glacier. Geikie,[68] Penck,[69] Dawson,[70] and Dall[71] have expressed the same opinion for the ground ice of Alaska, i. e., that they are accumulations of snow protected by layers of earth.

However, Tolmatschow says, "I take the liberty here of saying that I would not extend this conclusion to all the deposits of ice of Siberia and North America as considered by Toll in his work. I say only, that the properties of the ice from many places, described by this and other scientists, corresponds entirely to the Beresowka ice."

In attempting to follow the progressive steps by which ice-beds formed from either snow or water might become covered by a thickness of fifty feet of structureless clay sediment, the process seems entirely too rapid to be comprehended by present day experience and to be entirely incompatible with the facts. The deposition of clay required a body of comparatively quiet water and in the deposition of fifty feet of sediment it appears necessary to imply at least that depth of water over any bed of ice that might have existed before the clays were laid down. Also a considerable period of time for such clay sedimentation to transpire. The formation and continued existence of a bed of ice under water in this manner has been well remarked by Buckland to impose conditions such as to exclude the reasonable possibility of its occurrence. Such a condition as outlined above, however, appears to be called for if we accept Dall's supposition that the ice beds at Elephant Point are interstratified. That the arrangement presented at this locality in 1880-81 was simply due to a vertical displacement of fifty feet, more or less, by which a portion of the upper ice-bed appeared at a lower level is evident from Mr. Nelson's observation and section.[72]

The peculiar pungent odor that has been noticed by various observers in localities where mammoth and other mammal remains have been found associated with Pleistocene clays and Recent ice and peat beds, has been by some writers erroneously assigned to decaying animal matter. This odor is nothing more than gaseous emanations from decomposing vegetable matter. It is noticeable wherever exposures occur that favor the rapid thawing and oxi-

[68] Great Ice Age, p. 665.
[69] Deutsche geographische Blätter. Bd. IV, p. 174.
[70] Quart. Jour. Geol. Soc. Lond., Vol. L, pp. 1-9.
[71] Seventeenth Ann. Rep. U. S. Geol. Survey, 1896, p. 860.
[72] See Appendix, p. 111.

dizing of peat and humus and is more often found in situations where there are no traces whatever of animal remains. It is clearly and solely referable to decaying vegetable matter and in no case to animal matter in the Pleistocene clays.

It appears safe to assert that even when found intimately associated with mammal remains on talus slopes all occurrences of ice are to be considered more as an afterthought in studying the Pleistocene deposits of Alaska (and Siberia) with their fossil remains. The phenomena of Pleistocene and Recent are confused only superficially as is to be expected. The land ice bears no relation to the mammoth and its contemporary fauna beyond that the conditions of gradually increasing cold that have brought about the occurrence and preservation of the ice phenomena as exhibited today in Arctic and sub-Arctic regions was apparently also the primary cause of the extinction of the mammoth. The mammoth has become associated with ice because its remains have been found intermingled with ice on talus slopes. This is to be expected in clay bluffs overlain by beds of ice which in turn are covered by layers of peat or alluvium. In undergoing a vertical displacement due to the undermining of the sea or rivers, the ice may be fractured into large blocks by uneven stresses during its descent, the peaty covering become torn so fragments of it mixed with clay are washed down and over the new surface to fill up the cracks between the frozen blocks. Thus any mammoth or other remains that may be imbedded in the clays may become mixed heterogeneously with the re-sorted material among the ice blocks or lie exposed. Thus a frozen carcass may readily fall intact to find a secondary resting place in a crevasse between ice blocks and there be refrigerated.

XII.—SUMMARY OF CONCLUSIONS

I. That while remnants of the large Pleistocene mammal herds may have survived down to the Recent period and in some cases their direct descendants, as the musk-ox, to the present, most of them became extinct in Alaska with the close of Pleistocene.

II. The most rational way of explaining this extinction of animal life is by a gradual changing of the climate from more temperate conditions permitting of a forest vegetation much farther north than now, to the more severe climate of today, which subduing the vegetation and thus reducing the food supply besides directly discomforting the animals themselves, has left only those forms capable of adapting themselves to the Recent conditions surviving in these regions to the present.

III. There are no facts to support the contention that the climate of the Arctic and sub-Arctic regions ever has been colder than it is at present. There are no phenomena presented in those regions that require a more severe climate than that now existing to account for them. There are no ice deposits in Alaska, except those of large glaciers, that may be considered of Pleistocene age. There are no ice-beds interstratified with the Pleistocene deposits of Alaska.

IV. That the various forms of land ice, together with the deposits of peat, now existing throughout the Arctic and sub-Arctic regions of Alaska belong to the Recent period and these deposits may be most conveniently and logically classified by their *position* with reference to the Pleistocene and Recent formations and the ice deposits cannot be differentiated satisfactorily into deposits of snow or of water origin by their physical structure and character alone.

XIII.—APPENDIX

LITERATURE OF THE ELEPHANT POINT ICE-BEDS OF ESCHSCHOLTZ BAY IN KOTZEBUE SOUND, AND THOSE ON THE KOBUK RIVER

Kotzebue's Description

1821. Vol. I, p. 219.

Beechey's Description

1831. Vol. I. Part I. Narrative.
Part II. Appendix by Buckland.
1839. Vol. II. Zoology of Beechey's Voyage. Geology by Buckland, with map of Eschscholtz Bay colored by Belcher.

Descriptions by Seemann, Hooper, Dall, and others

1852. Botany of Voyage of the "Herald." Seemann.
Vol. I. Plate I. Picture of Ice-cliffs.
1853. Narrative of Voyage of the "Herald." Seemann.
Vol. II. Description of Ice-cliffs.
1854. Zoology Voyage of the "Herald." Richardson.
Description of Pleistocene mammal remains.
1881. Captain Hooper's description. July, 1880.
1881. W. H. Dall's description. September, 1880.
1883. Muir's remarks on soil and vegetation.
1884. Captain Hooper's observations in 1881. Nelson's photographs in Hooper's Rept. Nelson's MS. notes and drawings.
1887. Healy's Report on Cruise of Corwin in 1885. Lieut. Cantwell's Narrative of an Exploration of the Kowak (Kobuk) River. C. H. Townsend's notes.
1890. Lieut. Cantwell's letter to I. C. Russell. Lieut. Cantwell's Abstract in Science. Lieut. Cantwell's Account in National Geographic Magazine.

I. THE ICE-BEDS ON ESCHSCHOLTZ BAY IN KOTZEBUE SOUND

A discussion of the ice-beds of this so-called classic locality is reopened with some reluctance from the fact that the writer has never viewed the phenomena there presented. However, such a gross misconception of the significance of these ice-beds has become so generally accepted by repeated publication in what otherwise appear to be accepted authorities on the subjects they treat, that a thorough, careful, review of the testimony to date seems to be in order. To

present this impartially it appears necessary even if charged with much repetition and tediousness to reprint in accessible form all of the several descriptions of this locality, from that by its discoverer, Kotzebue, to the oft repeated and much quoted account by Dall, etc. Besides it seems desirable at this opportunity to bring together in chronological order all the scattered observations about this ice on the shores of Eschscholtz Bay that they may be available as a handy reference to future observers who may have the opportunity of visiting the locality and studying the facts.

[A VOYAGE OF DISCOVERY INTO THE SOUTH SEA AND BEERING'S STRAITS IN THE YEARS 1815-18. By Otto von Kotzebue. English translation in 3 vols. 8vo. London, 1821, Volume I.]

On the 7th of August, 1816, speaking of the native inhabitants about Eschscholtz Bay he says, page 218: "They perhaps also keep reindeer; as we saw many horns of these useful animals lying on the shore."

August 8, 1816, page 219. "We had passed a very unpleasant night, for it was stormy and rainy; and as the morning promised no better weather, I resolved to sail back to the ship; but scarcely had we gone half way, when we were overtaken by a violent storm from the southeast; the long-boat drew much water, and we were obliged to return to the landing-place we had just quitted. Being wet through, I had a fire made of driftwood, which we found everywhere in plenty; we dried our clothes, and prepared a refreshing soup. It seemed as if fortune had sent this storm, to enable us to make a very remarkable discovery, which we owe to Dr. Eschscholtz. We had climbed much about during our stay, without discovering that we were on real ice-bergs. The doctor, who had extended his excursions, found part of the bank broken down, and saw, to his astonishment, that the interior of the mountain, consisted of pure ice. At this news, we all went, provided with shovels and crows, to examine this phenomenon more closely, and soon arrived at a place where the bank rises almost perpendicularly out of the sea, to the height of a hundred feet; and then runs off, rising still higher. We saw masses of the purest ice, of the height of a hundred feet, which are under a cover of moss and grass; and could not have been produced, but by some terrible revolution. The place which, by some accident, had fallen in, and is now exposed to the sun and air [p. 220], melts away, and a good deal of water flows into the sea. An indisputable proof that what we saw was real ice, is the quantity of mammoths' teeth and bones, which were exposed to view by the melting, and among

which I myself found a very fine tooth. We could not assign any reason for a strong smell, like that of burnt horn, which we perceived in this place. The covering of these mountains, on which the most luxuriant grass grows to a certain height, is only half a foot thick, and consists of a mixture of clay, sand, and earth; below which the ice gradually melts away, the green cover sinks with it, and continues to grow; and thus it may be foreseen, that in a long series of years, the mountain will vanish, and a green valley be formed in its stead."

[NARRATIVE OF A VOYAGE TO THE PACIFIC AND BEERING'S STRAIT. By Captain F. W. Beechey, R. N. Vol. I. 4to, in two parts. London, 1831. Part I.]

July 29, 1826, page 257. "While the duties of the ships were being forwarded under my first lieutenant, Mr. Peard, I took the opportunity to visit the extraordinary ice-formation in Eschscholtz Bay mentioned by Kotzebue as being 'covered with a soil half a foot thick, producing the most luxuriant grass,' and containing an abundance of mammoth bones. We sailed up the bay, which was extremely shallow, and landed at a deserted village on a low sandy point, where Kotzebue bivouacked when he visited the place, and to which I afterwards gave the name of Elephant Point, from the bones of that animal being found near it.

"The cliffs in which this singular formation was discovered begin near this point, and extend westward in a nearly straight line to a rocky cliff of primitive formation at the entrance of the bay, whence the coast takes an abrupt turn to the southward. The cliffs are from twenty to eighty feet in height; and rise inland to a rounded range of hills between four and five hundred feet above the sea. In some places they present a perpendicular front to the northward, in others a slightly inclined surface; and are occasionally intersected by valleys and water-courses generally overgrown with low bushes. Opposite each of these valleys there is a projecting flat piece of ground, consisting of the materials that have been washed down the ravine, where the only good landing for boats is afforded. The soil of the cliffs is a bluish-coloured mud, for the most part covered with moss and long grass, full of deep furrows, generally filled with water or frozen snow. Mud in a frozen state forms the surface of the cliff in some parts; in others the rock appears [p. 258], with the mud above it, or sometimes with a bank half way up it, as if the superstratum had gradually slid down and accumulated against the cliff. By the large rents near the edges of the mud cliffs, they

appear to be breaking away, and contributing daily to diminish the depth of water in the bay.

"Such is the general conformation of this line of coast. That particular formation, which, when first discovered by Captain Kotzebue, excited so much curiosity, and bore so near a resemblance to an iceberg, as to deceive himself and his officers, when they approached the spot to examine it, remains to be described, as we rowed along the shore, the shining surface of small portions of the cliffs attracted our attention and directed us where to search for this curious phenomenon, which we should otherwise have had difficulty in finding, notwithstanding its locality had been particularly described; for so large a portion of the ice-cliff has thawed since it was visited by Captain Kotzebue and his naturalists, that only a few insignificant patches of the frozen surface now remain. The largest of these, situated about a mile to the westward of Elephant Point, was particularly examined by Mr. Collie, who on cutting through the ice in a horizontal direction, found that it formed only a casing to the cliff, which was composed of mud and gravel in a frozen state. On removing the earth above, it was also evident, by a decided line of separation between the ice and the cliff, that the Russians had been deceived by appearances. By cutting into the upper surface of the cliff three feet from the edge, frozen earth, similar to that which formed the face of the cliff, was found at eleven inches depth; and four yards further back the same substance occurred at twenty-two inches depth.

"This glacial facing we afterwards noticed in several parts of the sound; and it appears to me to be occasioned either by the snow being banked up against the cliff or collected in its hollows in the winter, and converted into ice in the summer by partial thawings and freezings—or by the constant flow of water during the summer over the edges of the cliffs, on which the sun's rays operate less forcibly than on other parts, in consequence of their aspect. The streams thus become converted into ice, either while trickling down the still frozen surface of the cliffs, or after [p. 259] they reach the earth at their base, in which case the ice rises like a stalagmite, and in time reaches the surface. But before this is completed, the upper soil, loosened by the thaw, is itself projected over the cliff, and falls in a heap below, whence it is ultimately carried away by the tide. We visited this spot a month later in the season, and found a considerable alteration in its appearance, manifesting more clearly than before the deception under which Kotzebue laboured."

July 30, 1826, Chapter XI, page 260. "On the 30th of July we

weighed from Chamisso Island attended by the barge, and steered out of the sound. The day was very fine; and as we sailed along the northern shore, the sun was reflected from several parts of the cliff, which our telescopes discovered to be cased with a frozen surface similar to that just described in Eschscholtz Bay."

In Narrative of the Proceedings of the Barge of the Blossom to explore the coast N. E. of Icy Cape:

"On the 21st of August arrived off Sea Horse Islands. Thence to Cape Franklin —" and "Having run twenty-nine miles along the coast to the northeast they again landed.—The coast here assumed a different aspect, and consisted of clay cliffs about fifty feet high, and presented an ice formation resembling that which has been described in Eschscholtz Bay. Their latitude was 70° 58′ 63″ N."

Monday, Sept. 11, 1826, page 322. "Having now the assistance of the barge, I embarked in her to examine narrowly the shores of Kotzebue Sound. Proceeding to survey the head of Eschscholtz Bay, shallow water obliged the boat to anchor off Elephant Point, where I left Mr. Collie with a party to examine again the cliffs in which the fossils and ice formation had been seen by Kotzebue, and proceeded to the head of the bay in a small boat. We landed upon a flat muddy beach, and were obliged to wade a quarter of a mile before we could reach a cliff for the purpose of having a view of the surrounding country. * * *

"The shore around us was flat, broken by several lakes, in which there was a great many waterfowl. The cliff we had ascended was composed of a bluish mud and clay, and was full of deep chasms lying in a direction parallel with the front of the cliff. In appearance the cliff was similar to that at Elephant Point, which was said to contain fossils; but there were none seen in this one, though the earth, in parts, had a disagreeable smell, similar to that which was supposed to proceed from the decayed animal substances in the cliff near Elephant Point. * * * "

Page 323. "I found Mr. Collie had been successful in his search among the cliffs at Elephant Point, and had discovered several bones and grinders of elephants and other animals in a fossil state of which a full description and drawings from the remains will be found in the appendix. Associating these two discoveries, I bestowed the name of Elephant upon the point, to mark its vicinity to the place where the fossils were found; and upon the river that of Buckland, in compliment to Dr. Buckland, the professor of geology at Oxford, to whom I am much indebted for the above mentioned description of the fossils, and for the arrangement of the geological memoranda attached to this work.

"The cliff in which these fossils appear to have been imbedded is part of the range in which the ice formation was seen in July. During our absence (a space of five weeks) we found that the edge of the cliff in one place had broken away four feet, and in another two feet and a half, and a further portion of it was on the eve of being precipitated upon the beach. In some places where the icy shields had adhered to the cliff nothing now remained, and frozen earth formed the front of the cliff. By cutting through those parts of the ice which were still attached, the mud in a frozen state presented itself as before, and confirmed our previous opinion of the nature of the cliff. Without putting to this test, appearances might well have led to the conclusion come to by Kotzebue and M. Eschscholtz; more especially if it happened to be visited early in the summer, and in a season less favorable than that in which we viewed it. The earth, which is fast falling away from the cliffs—not in this place only, but in all parts of the bay—is carried away by the tide. * * *

" In consequence of this shallow water there was much difficulty in embarking the fossils, the tusks in particular, the largest of which weighed 160 lbs."

September 25, 1826, page 329. " In another excursion which I made along the north side of the sound, I landed at a cape which had been named after the ship (Blossom), and had the satisfaction of examining an ice formation of a similar nature to that in Eschscholtz Bay, only more extensive and having a contrary aspect. The ice here, instead of merely forming a shield to the cliff, was imbedded in the indentations along its edge, filling them up nearly even with the front. A quantity of fallen earth was accumulated at the base of the cliff, which uniting with the earthy spaces intervening between the beds of ice, might lead a person to imagine the ice formed the cliff, and supported a soil two or three feet thick, part of which appeared to have been precipitated over the brow. But on examining it above, the ice was found to be detached from the cliff at the back of it; and in a few instances so much so, that there were deep chasms between the two. These chasms are no doubt widened by the tendency the ice must have towards the edge of the cliff; and I have no doubt the beds of ice are occasionally loosened and fall upon the beach, where, if they are not carried away by the sea, they become covered with the earthly materials from above, and perhaps remain sometime immured. In some places the cliff was undermined, and the surface in general was very rugged; but it was evident in this, as in the former instance, that the ice was lodged in the hollow places in the cliff."

October 7, 1826, page 333. "Mr. Elson went up Eschscholtz Bay with two boats for [p. 334] the purpose of sounding and obtaining further information of Buckland River. * * * The barge brought us down a valuable addition to our collection of fossils, the cliff having broken away considerably since the first specimens were obtained."

Part II, page 560, September 18, 1827. "On the 18th a party of the officers landed in Eschscholtz Bay to search for fossils, but they were unsuccessful, in consequence of an irregularity of the tide, which was on that occasion unaccountably high, and scarcely fell during the day. The cliffs had broken away considerably since the preceding year; and the frozen surface of the cliff appeared in smaller quantities than before, but the earth was found congealed at a less depth from the top. This examination tended to confirm more steadfastly the opinion that the ice forms only a coating to the cliff, and is occasioned by small streams of water oozing out, which either become congealed themselves in their descent, or convert into ice the snow which rests in the hollows."

[CAPTAIN F. W. BEECHEY. NARRATIVE OF A VOYAGE TO THE PACIFIC AND BEERING'S STRAIT. Part II, 1831, pp. 593-612. 3 plates. Appendix.—On the Occurrence of the remains of Elephants, and other Quadrupeds, in the cliffs of frozen mud, in Eschscholtz Bay, within Beering's Strait, and in other distant parts of the shores of the Arctic seas. By the Rev. Wm. Buckland, D. D., F. L. S., F. G. S., and professor of geology and mineralogy in the University of Oxford.]

"Having been requested, at the time of Captain Beechey's return to England, 1828, to examine the collection of animal remains which he brought home from the shores of Eschscholtz Bay, and to prepare a description of them for the present publication, I attended at the Admiralty to assist at the opening and distribution of these specimens. The most perfect series, including all the specimens, engraved in plates 1, 2, 3 (fossils), was selected for the British Museum; another series, including some of the largest tusks of elephants, was sent to the Museum of the College of Edinburg, and other tusks to the Museum of the Geological Society of London. To the plates of these fossils, I have added a map of the bay in which they were collected,[1] on the same spot where similar remains were first discovered by Lieutenant Kotzebue and Dr. Eschscholtz, on the 8th of August,

[1]This map was not published until 1839 when it appeared along with other geological notes at the end of the volume on the Zoology of Captain Beechey's Voyage.

1816. Captain Beechey, in the course of his narrative (pp. 257, 323, and 560), has given a general description of the circumstances attending the examination of the locality in which the existence of these bones had been indicated by Lieutenant Kotzebue, and before I proceed to offer any observations of my own on these remarkable organic remains, or on the causes that may have collected them in such abundance on the spots where they are now found, I shall extract a further and more detailed account of the place and circumstances in which they were discovered, from the journals of Mr. Collie (surgeon to the English Expedition), by whom the bones were principally collected, and the chief observations and experiments made, on which Captain Beechey has founded his opinion, in which his officers, Lieutenant Belcher and Mr. Collie, entirely coincide with him, that the cliffs containing bones, which have been described by Kotzebue and Eschscholtz as icebergs covered with moss and grass, are not composed of pure ice, but are merely one of the ordinary deposits of mud and gravel, that occur on many parts of the shores of the Polar Sea, being identical in age and character with diluvial deposits of the same kind which are known to be dispersed over the whole of Europe, and over a large part of northern Asia and North America; and presenting no other peculiarities in the frozen regions of the north, than that which results from the present temperature of these regions, causing the water which percolates this mud and gravel to be congealed into ice.

"The question of fact, whether the cliffs containing these bones of elephants, and other land quadrupeds, are composed of 'masses of the purest ice, a hundred feet high, and covered on their surface with vegetation,' as stated in the voyage of Lieutenant Kotzebue (p. 219, English translation), or are simply composed, as Captain Beechey thinks them to be, of ordinary diluvium, having its interstices filled up with frozen waters, is important, as it affects materially the consideration of the further question, as to what was the state of the climate of the arctic regions at the time when they were thickly inhabited by genera of the largest quadrupeds, such as at present exist only in our warmest latitudes; this being a point of much interest and curiosity, in relation to the history of the physical revolutions that have affected our planet, and on which there still exists a difference of opinion among those individuals who have paid the greatest attention to the subject.

"Before I proceed to Mr. Collie's observations on the spot in which they were found, I shall extract from his journal a list of the total number of animal remains collected during the short time

he was with Captain Beechey in Eschscholtz Bay, and add my own list and description of the most perfect of these specimens, which I have selected to be engraved.

"List, showing the total number of animal remains collected in Eschscholtz Bay, taken from the journal of Mr. Collie:

"*Elephant*:—1 lower jaw, nearly complete; 7 molar teeth; 9 tusks. Five of them large, and weighing from one hundred to one hundred and sixty pounds each. Four small; one of these was found in the debris of the cliff half way up; the circumference of the largest tusk at its root is twenty inches, and at three feet above the root twenty-one inches and a half; another tusk, in which part of the tip is wanting, measures nine feet two inches along the curve from the root to the tip, and five feet two inches across the chord of its curve; 4 fragments of tusks; 3 dorsal vertebræ, five inches and a half in diameter; 1 atlas; 1 os innominatum, nearly perfect; 1 ilium, imperfect; 1 os pubis, imperfect; 4 fragments of scapulæ, one of them tolerably complete; 1 portion of humerus; 5 femora, one of them almost complete; 4 fragments of femora; 2 tibiæ, one of them nearly complete; 1 tarsal bone; 1 os calcis, entire, taken out of the cliff; 1 cuboides, nearly entire; 1 cuneiform; 1 phalangal bone.

"*Urus*:—1 skull, incomplete; 3 fragments of horns; 1 femur; 3 tibiæ; 1 dorsal vertebra; 1 sacrum.

"*Musk-ox*:—1 skull, with horns attached, incomplete and very modern.

"*Deer*:—1 fragment of antler; 4 tibiæ entire; 3 metatarsal bones; 1 os calcis. Some of these are probably casual and modern, and derived from reindeer that now frequent this part of America.

"*Horse*:—1 astragalus; 1 metacarpus; 1 metatarsus."

[BUCKLAND'S APPENDIX. Notes extracted from the Journal of Mr. Collie.]

[598] " The attention of the world has been called to the remarkable cliff in which fossil bones were found by Dr. Eschscholtz in August, 1816. On my first visit to it in the month of July, 1826, time did not permit me to do more than take a view of the most eastern part, and examine the nature of the icy fronting which is presented. At that time I saw no traces of fossils; this cliff faces to the north, and extends in nearly a right line, with few interruptions, for two miles and a half, and is in general about ninety feet high. It is composed of clay and very fine quartzy and micaceous sand, assuming a grayish appearance when dry. The land behind rises gradually to an additional height of one hundred feet, and is covered with a black, boggy soil, nourishing a brown and gray lichen, moss, several species of

ericæ, graminiæ, and other herbaceous plants, and is intersected with a few valleys containing small streams, and having their more protected declivities adorned with shrubs of willow and dwarf betula (*Betula incana*).

"A continued waste of the cliff is produced at the upper part by its falling down in considerable lumps to the bottom, where the debris remains for a longer or shorter time, and covers the front to a greater or less height, in some places, almost to the very top. Large masses are sometimes seen rent off and standing out from the body of the cliff ready to have their last slight hold washed away by the next shower, or by a little more thawing and separation of the frozen earth that serves them for attachment. The lumps of soil that fall are still covered with the herbaceous and shrubby verdure that grew upon them. The perpendicular front of the cliff of frozen mud and sand is every summer gradually decreasing by the melting of the ice between its particles into water, which trickles down and carries with it loose particles of earth. In some portions of the cliff the earthy surface is protected with ice, partly the effect of snow driven into the hollows and fissures, and partly from the congealation of water, which may have collected in chinks or cavities: these masses of ice dissolve in summer, and the water running from them carries with it any earth that lies in its way, and mixes itself with, and moves forward, the mass of debris below. By this gradual thawing and falling of the cliff, the black boggy soil at the surface becomes undermined, and assumes the projecting and overhanging appearance which is so remarkable. At the base of the greater part of the cliff the debris is washed by the sea at full tide, and being gradually carried away by the retiring waters, is spread out into an extensive shoal along the coast. It was in this shoal, where it is left dry by the ebbing tide, to the distance of fifty or a hundred yards from the cliff, that the greater number of the fossil bones and teeth were discovered, many of them so concealed as only to [599] leave a small end or knob sticking up; they were dispersed very irregularly. Remains of the musk-ox were found on this shoal, along with those of elephants.

"The few specimens taken out of the cliff, or more properly from the debris, on the front of it (for none, I believe, were taken out of the very cliff), were in a better state of preservation than those which had been alternately covered and left exposed by the flux and reflux of the tide, or imbedded in the mud and clay of the shoal.

"A very strong odour, like that of heated bones, was exhaled wherever the fossils abounded. Quantities of rolled stones, mostly

of a brownish sandstone, lay upon the shoal, left dry by the receding sea. With these were also porphyritic pebbles.

"Parts of some of the tusks, where they had been imbedded in the clay and sand, were coloured blue by phosphate of iron, and many of the teeth were stained in the same manner. The circular layers of the tusks in the more decayed specimens were distinctly separated by a thin vein of fibrous gypsum.

"In those parts of the bay where there are no cliffs, the waves are kept at a distance from the land by a gravelly beach, which they have thrown up for a considerable extent round the entrance of the streams which come down the valleys. These beaches have formed rounded flats containing marshes or lakes: not unfrequently a rather luxuriant herbage covers their surface. The land behind them rises in a gentle slope. Great part of the shore of Kotzebue Sound is made up of a diluvial formation, similar to that on the south shore of Eschscholtz Bay. From Hut Peak to Hotham Inlet it exhibits many cliffs similar to those just described, and also others with a uniform and steep slope, partly covered with verdure, and partly exposing the dry sand and clay which compose them. The most elevated cliffs form the projecting headland of Cape Blossom, and *abound in ice, notwithstanding their southern aspect*; particularly at Mosquito station and Cape Blossom. In their neighborhood I observed the natives had recently formed coarse ivory spoons from the external layer of a fossil elephant's tusk. The ice here in the end of September showed itself more abundantly than it did in the middle of the same month on the cliffs in Eschscholtz Bay which have a northern aspect.

"Mr. Collie then proceeds to explain still further his ideas of the manner in which masses and sheets of pure ice may have been collected in hollows and fissures on and near the front of the cliff in Eschscholtz Bay.

"'1st. By the accumulation of snow drifted into hollows subjacent to the overhanging stratum of black boggy soil that forms the brink of the cliff, and subsequently converted into ice by successive thawing and freezing in spring and summer.

[600] "'2dly. They may have been formed from water collected in deep fissures and cavities that intersect the falling cliff near its margin. The inclined position of the land immediately above this margin of peat, and the annual undermining which is produced by the thawing of the frozen mud beneath it, produce occasional land slips and movements of the edge of the cliff towards the sea; these cause cracks and fissures of the soil in various directions, but chiefly

parallel to the external face of the cliff. When these fissures descend through the black boggy soil of the surface into the frozen mud below, they become receptacles for the formation of ice, since the water that oozes into them is congealed upon their sides until it entirely fills them with a wall or dyke of solid ice. The fall of a mass of mud from the outer side of one of these walls would expose this ice, forming a case over the inner side of the fissure in which it was accumulated.

" ' 3dly. The manner in which an extensive facing of pure ice may be formed on these cliffs, by water during the summer trickling down their frozen surface from the soil above, and becoming converted to ice in the course of its descent, has been described by Captain Beechey [pages 258 and 330].'

" Lieutenant Belcher, in his notes, proposes another theory to explain the occurrence of masses of pure ice immediately below the margin of the peat on the top of the cliff on the southern shore of Eschscholtz Bay. He concieves that between the superficial bed of spongy peat, and the mass of frozen mud which forms the body and substance of this cliff, the water oozing downwards through the peat, during the thaw of each successive summer, is stopped at the point where it comes into contact with the perpetually frozen earth below, and there accumulates into a thick horizontal sheet of pure transparent ice, and that it is the broken edge of this icy stratum which becomes exposed in the margin of the cliff during the process of slow and gradual destruction which it is continually undergoing.

" This opinion, however, is, I believe, peculiar to Lieutenant Belcher. The experiment made by Mr. Collie in boring horizontally into the cliff, through a vertical face of ice, until he penetrated the frozen mud behind it, shows, that in this case the ice was merely a superficial facing of frozen water, consolidated as it descended the front of the cliff; and his further experiments in digging vertically downwards, in two places, through the peat into frozen mud, and finding no traces of any intermediate bed of ice appear unfavorable to any hypothesis as to the formation of a stratum of pure ice between the superficial peat and subjacent mud.

" It has just been stated that Captain Beechey and Mr. Collie propose three different solutions to explain the origin of these hanging masses of ice near the upper margin of vertical cliffs: 1st, That they may have been formed from snow drifted into hollows of the cliffs, and subsequently converted into ice; 2dly, From [601] water consolidatetd into ice within fissures and cavities, caused by the subsidence and falling forwards of the frozen mud; 3dly, From water

trickling down the external surface of the cliff, and freezing as it descended. To these the theory of Lieutenant Belcher would add a fourth process, by which a horizontal bed of ice is formed between a superficial bed of peat and the subjacent mud. These hanging masses of ice, whatever may be their origin, appear to have been so abundant at the time of the Russian expedition to this coast, as to have made Kotzebue and Eschscholtz imagine the entire cliff behind them to be an iceberg; an opinion in which all the English officers agree in considering to be erroneous, since the view and descriptions of the cliff on the south shore of Eschscholtz Bay, given on page 219 of the English translation of Kotzebue's Voyage, do not correspond with the state of this coast when it was subsequently visited by the crew of the Blossom.

[Dr. Buckland here gives Captain Kotzebue's observations quoted on preceding page which are not here repeated.]

"Mr. Collie's experiments, which I have before alluded to, in digging both horizontally and vertically through the ice and peat into frozen mud, show that, at the points where they were made, the cliff formed no part of any iceberg. Still more decisive is the important fact, that on the two occasions when it was [602] visited by the English expedition, the patches of ice upon the cliff in question were very few in number, and variable from one year to another; that the 'masses of the purest ice to the height of a hundred feet, which were seen by the Russian officers, had entirely vanished; and that nearly the whole front of the cliff, from the sea at its base to the peat that grew on its summit, presented a continuous mass of indurated mud and sand, or of under-cliffs formed by the subsidence of these materials.

"It seems quite certain, therefore, that there must have been a material change in the quantity of ice on the cliff in Eschscholtz Bay in the interval between the visits of Lieutenant Kotzebue and Captain Beechey; and if we suppose that, during this interval, there was an extensive thawing of the icy front that was seen by Kotzebue, but which existed not at the time of Beechey's visit, we find in this hypothesis a solution of the discrepancy between these officers; since what to the first would appear a solid iceberg, when it was glazed over with a case of ice, would, after the melting of that ice, exhibit to the latter a continuous cliff of frozen diluvial mud. Whilst the ice prevailed all over the front of the cliff, any bones that had fallen from it before the formation of this ice, and which lay on the under-cliffs or upon the shore, must, by an error almost inevitable, have been presumed to fall from the imaginary iceberg.

"This circumstance seems to suggest to us that it is worthy of consideration whether or not there may have existed any similar cause of error in the case of the celebrated carcass of an elephant in Siberia, which is said to have fallen entire from an iceberg in the cliffs near the Lena. The Tungusian who discovered this carcass suspended in what he called an iceberg may possibly have made no very accurate distinction between a pure iceberg and a cliff of frozen mud.

"It is stated by Lieutenant Belcher, that at a spot he visited on the southeast shore of Eschscholtz Bay, on ascending what appeared at first to be a solid hillock, he found a heap of loose materials, unsafe to walk on, and having streams of liquid mud oozing from it on all sides through coarse grass; that as the melting subsoil of the hillock sinks gradually down, the incumbent peat subsides with it; so that at no very distant period the entire hillock will disappear. In other mud cliffs, also, he observed similar streams of liquid mud, accompanied by a depression of the surface immediately above them. Thus, from the month of June to October these cliffs are constantly thawing, and throwing down small avalanches of mud, which between Cape Blossom and Cape Kruzenstern, are so numerous that you can scarce stand there an hour without witnessing the downfall of some portion of the thawing cliffs. Hence originates a succession of ravines and gullies, which do not run far inland, and afford no sections, being covered with the debris of the [603] superficial peat that falls into them. Small streams of muddy water, of the consistency of cream, ooze from the sides of these ravines, the water being supplied by the melting of the particles of ice which pervade the substance of the frozen mud and peat.

"There remain, then, three important points, on which all the English officers concur in the same opinion: 1st, That the bones and tusks of elephants at Eschscholtz Bay are not derived from the superficial peat; 2dly, That they are not derived from any masses of pure ice; 3dly, That, although collected chiefly on the shore at the base of the falling cliff, they are derived only from the mud and sand of which this cliff is composed.

"The occurrence of cliffs composed of diluvial mud is by no means peculiar to the south shore of Eschscholtz Bay. It will be seen by reference to the map (Plate I, Geology), that they are more extensive, but at a less elevation along the north shore of the same bay, and also on the southwest of it, at Shallow Inlet, in Spafarief Bay. Indeed, in following the line of coast north-eastwards, from the Arctic Circle, near Beering's Strait, to lat. 71° N., wherever the

coast is low, there is a long succession of cliffs of mud, in the following order: 1. Schischmareff Inlet. 2. Bay of Good Hope, on the south of Kotzebue Sound. 3. Spafarief Bay, at the southeast extremity of Kotzebue's Sound. 4. Elephant Point, in Eschscholtz Bay. 5. At the mouth of the Buckland River, at the head of Eschscholtz Bay. 6. The north coast of Eschscholtz Bay. 7. Cape Blossom. 8. Point Hope. 9. From Cape Beaufort to twenty miles east of Icy Cape. 10. Lunar Station, near lat. 71°. At the base of the mud cliff, fifteen feet high, in the Bay of Good Hope, a small piece of a tusk of an elephant was found upon the shore. At Shallow Inlet, the mud cliff was fifteen feet high, without any facings of ice, or appearance of bones; yet there was the same smell at low water as in the cliffs near Elephant Point, that abound so much in bones. At Icy Cape, the cliffs of mud behind the islands were about twenty feet high, but were not examined. Patches of pure ice were observed hanging on the mud cliffs in many places along this coast, but only where there was peat at the top; hence it may be inferred, that the ice, in such cases, is formed by water oozing from the peat. At High Cape, near Hotham Inlet, is a cliff of mud, a hundred feet high, covered at the top with peat, and having patches of ice upon its surface; but no bones were found here. In those parts of the coast where the cliffs are rocky there were no facings of ice.

"Having thus far stated the evidence we possess respecting the facts connected with the discovery of these bones in Eschscholtz Bay, I will proceed to offer a few remarks in illustration and explanation of them, and to consider how far they tend [604] to throw light on the curious and perplexing question, as to what was the climate of this portion of the world at the time when it was inhabited by animals now so foreign to it as the elephant and rhinoceros, and as to the manner in which, not only their teeth and tusks and dislocated portions of their skeletons, but in some remarkable instances, the entire carcasses of these beasts, with their flesh and skin still perfect, became entombed in ice, or in frozen mud and gravel, over such extensive and distant regions of the northern hemisphere.

"The bones from Eschscholtz Bay, like most of those we find in diluvial deposits, are no way mineralized; they are much altered in colour, being almost black, and are to a certain degree decomposed and weakened; yet they retain so much animal matter, that not only a strong odour like that of burnt horn is emitted from them on the application of heated iron, but a musty and slightly ammoniacal smell is perceptible on gently rubbing their surface.

"It must not, however, be inferred that this high state of preser-

vation can exist only in bones that have been imbedded in frozen mud or frozen gravel, since dense clay impermeable to water has been equally effective in preserving the remains of the same extinct species of animals in the milder climate of England. There are in the Oxford Museum bones of elephant and rhinoceros from diluvial clay, in Warwickshire and Norfolk, that are scarcely at all more decomposed than those brought by Captain Beechey from Eschscholtz Bay, and are nearly of the same color and consistence with them. I have also a fragment of the tusk of an elephant from the coast of Yorkshire, near Bridlington, of which great part had been made into boxes by a turner of ivory before the remainder came into my possession; and on comparing the state of the residuary portion of this tusk from Yorkshire with that of the scoop made of a fossil tusk by the Esquimaux in Eschscholtz Bay, I find the difference scarcely appreciable.

"It is mentioned, both by the Russian and English officers, that a strong odour like that of burnt bones is emitted from the mud of the cliffs in which they discovered these animal remains in Eschscholtz Bay; other observers have stated the same thing of the mud cliffs in Siberia, near the mouth of the Lena, which contain similar organic remains. But it is also stated by Mr. Collie that a like odour was perceived at the base of another mud cliff in Shallow Inlet, near Eschscholtz Bay, where there were no bones; and as in this latter case we must attribute it to some cause unconnected with the bones, and probably to gaseous exhaltations from the mud itself, we may, I think, draw the same inference as to the origin of the odour in all the other cases also; thus in Eschscholtz Bay, where nearly all the bones were collected at the base of the cliff on the beach below high water, how can the presence of two or three bones only, lying half way up the cliff, account for the odour which is emitted over a distance of more than a mile along this shore? How inadequate is a cause so partial to so general an effect! since, however numerous may be the animal remains that are buried in the interior of the cliff, no exhalations from them can escape through their impenetrable matrix of frozen mud; and even if that fallen portion of mud which constitutes the under-cliff be ever so abundantly loaded with fossil bones, it is scarcely possible that these should undergo such rapid decomposition as to transmit strong exhalations to the surface through so dense a substance as saturated clay; in fact, their high degree of preservation shows that no such rapid decomposition has taken place.

"With respect to the matrix of frozen mud, from which these

remains are said to be derived, it appears, from specimens of it adhering to the bones, that it consists of micaceous sand and quartzose sand, intermixed with fine blue clay. In a hollow of one of the tusks I found a quantity of this compound, and some fragments of mica slate. All these ingredients may have been derived from the detritus of primitive micaceous slates, such as constitute a large part of the fundamental rocks of the neighborhood of Eschscholtz Bay.

"Pebbles of porphyry also are said to occur in the cliff, and also on the beach below it, mixed, in the latter case, with pebbles of basalt and sandstone, and a few large blocks of basalt. No rock was noticed in this district from which these rolled stones could have been derived; some of those upon the beach may possibly have been drifted thither on floating icebergs. The tranquil state and retired position of the bay render it improbable that these pebbles have been brought to their present place by the influence of any existing submarine currents.

"It is important to clear from confusion two facts mentioned by Captain Beechey, viz., the occurrence of remains of the reindeer and of the musk-ox along with bones of the elephant in Eschscholtz Bay. Had the bones of either of these arctic animals been found unequivocally mixed with the bones of elephants in any undisturbed part of the high cliff, it would have followed that the reindeer and the musk-ox must have been co-eval with the fossil elephant; and this fact would have been nearly decisive of the question as to the climate of this region at the time when it was inhabited by these three species of animals. But as all the fossil remains collected in Eschscholtz Bay, with the exception of a very few bones and the tusk of an elephant that lay high up in the under cliff, were collected on the beach between high and low-water mark, nothing is more probable than that the bones of modern animals should become mixed with those of fossils after they had fallen upon the beach in the recesses of a quiet bay.

"Kotzebue (vol. 1, p. 218) says he saw many horns of reindeer lying on the shore in Eschscholtz Bay, and conjectures that the Americans, who frequent these [p. 606] coasts occasionally in the hunting season, may have brought with them the reindeer from which these horns had been derived. This hypothesis may explain the presence of such horns in a spot which no wild reindeer are known to frequent at present; but as Kotzebue [p. 219] mentions also the abundance of drift-wood upon the shores of this bay, it is probable that the same currents which brought the wood may have

also brought the carcasses of reindeer, and have stranded them on the shores where their horns were found.

"The agency of the same currents to which I have referred the drifting of the carcasses of reindeer into Eschscholtz Bay will also equally explain the presence of recent bones of the musk-ox in this bay on the same shoal with the bones of elephants that had fallen from the cliff. I have already stated that the condition of the skull and horns of a musk-ox, which were brought home with the fossil bones, is so very recent, and differs so essentially from the condition of all the bones of elephants from this place, that it is impossible it can have been buried in the same matrix with them; for, in such case, all would have been nearly in the same state, either of preservation or decay.

"It is stated by Cuvier,[1] that a similar doubt is attached to the heads of musk-oxen described by Pallas and Ozeretzkovsky, as found near the mouth of the Ob, and at the embouchure of the Yana, and that there is yet no sufficient proof of the existence of any fossil species of musk-ox that may be considered of the same age with the fossil elephant, or which can be brought in evidence as to the question of the climate of the polar regions when these elephants were living. Of the very few remains of musk-oxen which have yet been found, it does not appear that any have been buried at a great depth.

"There is nothing peculiar to Eschscholtz Bay in the occurrence of bones of horses with those of elephants; from the number of localities in which their teeth and bones have been found together, in diluvial deposits, it appears that more than one species of horse was co-extensive with the fossil elephant in its occupation of the ancient surface of the earth. Wild horses are at present almost unknown, except in warm or temperate latitudes.

"We may now consider how far the facts we have collected respecting the bones in Eschscholtz Bay are in accordance with similar occurrences, either in the adjoining regions to the north, or in other still more distant parts of the earth, and in different latitudes.

"It is stated by Pallas in the 17th volume of the New Commentaries of the Academy of Petersburg, 1772, that throughout the whole of northern Asia, from the Don to the extreme point nearest America, there is scarce any great [607] river in whose banks they do not find the bones of elephants and other large animals which cannot now endure the climate of this district, and that all the fossil

[1] Ossemens Fossiles, second edition, Vol. IV, p .165.

ivory which is collected for sale throughout Siberia is extracted from the lofty, precipitous, and sandy banks of the rivers of that country; that in every climate and latitude, from the zone of the mountains in central Asia to the frozen coasts of the Arctic Ocean, all Siberia abounds in these bones, but that the best fossil ivory is found in the frozen lands adjacent to the Arctic Circle; that the bones of large and small animals lie in some places piled together in great heaps, but, in general, they are scattered separately, as if they had been agitated by waters, and buried in mud and gravel.

"The term mammoth has been applied indiscriminately to all the largest species of fossil animals, and is a word of Tartar origin, meaning simply 'animal of the earth.' It is now appropriated exclusively to the fossil elephant, of which one species only has been yet established, differing materially from the two existing species, which are limited, one to Asia, the other to Africa.

"Of all the fossil animals that have been ever discovered, the most remarkable is the entire carcass of a mammoth, with its flesh, skin, and hair still fresh and well preserved, which in the year 1803 fell from the frozen cliff of a peninsula in Siberia, near the mouth of the Lena.* Nearly five years elapsed between the period when this carcass was first observed by a Tungusian in the thawing cliff, in 1799, and the moment when it became entirely disengaged, and fell down upon the strand, between the shore and the base of the cliff. Here it lay two more years, till great part of the flesh was devoured by wolves and bears; the skeleton was then collected by Mr. Adams and sent to Petersburg. Many of the ligaments were perfect, and also the head, with its integuments, weighing four hundred and fourteen pounds without the tusks, whose weight together was three hundred and sixty pounds. Great part of the skin of the body was preserved, and was covered with reddish wool and black hairs; about thirty-six pounds of hair were collected from the sand, into which it had been trampled by the bears.

"The following description, by Mr. Adams, of the place in which this mammoth was found will form an interesting subject of comparison with Captain Beechey's account of the cliff in Eschscholtz Bay: 'The place where I found the mammoth is about sixty paces distant from the shore, and nearly a hundred paces from the escarpment of the ice from which it had fallen. This escarpment occupies

*The details of this case are published by Dr. Tilesius in the fifth volume of the Memoirs of the Academy of Petersburg, and also by Mr. Adams in the Journal du Nord, printed at Petersburg in 1807.

exactly the middle between the two points of the peninsula, and is two miles long; and in the place where the mammoth was found, this *rock* has a [608] perpendicular elevation of thirty or forty toises (from 180 to 240 feet). Its substance is a clear pure ice; it inclines towards the sea; its top is covered with a layer of moss and friable earth fourteen inches in thickness. During the heat of the month of July a part of this crust is melted, but the rest remains frozen. Curiosity induced me to ascend two other hills at some distance from the sea; they were of the same substance, and less covered with moss. In various places were seen enormous pieces of wood of all the kinds produced in Siberia; and also mammoths' horns, in great numbers, appeared between the hollows of the rocks; they all were of astonishing freshness. The escarpment of ice was from thirty-five to forty toises high; and according to the report of the Tungusians, the animal was, when they first saw it, seven toises below the surface of the ice. * * *'

"I have to observe in this passage, that it contains no decisive evidence to show that the ice seen by Mr. Adams on the front of the cliff from which the elephant had fallen was anything more than a superficial facing, similar to that found by Captain Beechey on parts of the front of the earthy cliff in Eschscholtz Bay; the same cliff which, a few years before, when visited by Kotzebue, seems to have been so completely incased with a false fronting of ice as to induce him to consider the entire hill to be a solid iceberg. One thing, however, is certain as to this mammoth, viz., that whether it was imbedded in a matrix of pure ice or of frozen earth, it must have been rapidly and totally enveloped in that matrix before its flesh had undergone decay, and that whatever may have been the climate of the coast of Siberia in antecedent periods, not only was it intensely cold within a few days after the mammoth perished, but it has also continued cold from that time to the present hour.

"Remains of the rhinoceros also appear to be nearly co-extensive with those of the elephant in these northern regions. Pallas mentions the head of a rhinoceros which was found near Lake Baikal, near Tshikoi, and four heads and five horns of this animal from various parts of Siberia on the Irtis, the Alei, the Obi, and the Lena. These horns in the frozen districts are so well preserved that splices of them are used by the natives to strengthen their bows.

"Pallas conceived that these remains are not derived from animals that ever inhabited Siberia, but from carcasses drifted northward from the southern regions by some violent aqueous

catastrophe, and that there is proof both of the violence and suddenness of this catastrophe in the phenomenon of an entire rhinoceros found with its skin, tendons, ligaments, and flesh preserved in the *frozen soil* of the coldest part of eastern Siberia. On the arrival of Pallas in Ircutia in March, 1772, the head of this animal was laid before him, together with two of its feet, having their skin and flesh hardened like a mummy; it had been found in December, 1771, in [609] the sand banks of the Wiluji, which runs in about 64° of north latitude into the Lena; the head and two feet only were taken care of, the rest of the carcass, though much decayed, was still enclosed in its skin, and was left to perish; the bones were yellow, the foot had on its skin many hairs and roots of hairs. On various parts of the skin were stiff hairs from one to three inches long.

"If we compare these phenomena of the arctic regions with those of other countries, and especially with England, we shall find it by no means peculiar to the northern extremities of the world to afford extensive deposits of diluvial mud and gravel, containing the remains of extinct species of the elephant and rhinoceros, together with those of horses, oxen, deer, and other land quadrupeds. A large portion of the east coast of England, particularly of Essex, Suffolk, Norfolk, Yorkshire, and Northumberland, is composed of similar deposits of argillaceous diluvium, loaded in many places with bones of the same species of quadrupeds; these deposits occur not only on the low grounds and lands of moderate elevation, but also on the summits of the highest hills, e. g., on the chalky cliff of Flamborough Head, four hundred and thirty feet above the sea. In the central parts of England, near Rugby, we have similar deposits, containing bones, tusks, and teeth of the same species of animals. In Scotland we have the same argillaceous diluvium on the east coast, near Peterhead, and near the western coast, at Kilmours, in Ayrshire, where it contains tusks of elephants and bones.

"The analogies which these deposits offer to those in the arctic regions are striking. In both cases the bones are of the same species of animals. In both cases they are imbedded in superficial deposits of mud and gravel of enormous extent and thickness. In both cases the deposits derive no accession from existing causes, and are suffering only continual loss and destruction by the action of the atmosphere, of rivers, and of the sea. Their chief peculiarity in the polar regions seems to consist in the congealation, to which the diluvium itself as well as the remains included in it are subject, from the influence of the present polar climate. Examples might

be quoted to show the occurrence of similar remains in diluvial deposits all over Europe, and largely in America. Having then such extensive accumulations of the bones of animals, and the detritus of rocks, all apparently resulting from the simultaneous action of water, but which the operation of existing seas and rivers in the districts occupied by this detritus can never have produced, and are only tending to destroy, we may surely be justified in referring them all to some adequate and common cause, such as the catastrophe of a violent and general inundation alone seems competent to have afforded.

"The facts we have been considering are obviously much connected with the still unsettled question respecting the former climate and temperature of that part [p. 610] of the earth in which they occur. Too much stress has, I think, been laid on the circumstances of the mammoth in Siberia being covered with hair. We have living examples of animals in warm latitudes which are not less abundantly covered with hair and wool in proportion to their size than the elephant at the mouth of the Lena. Such is the hyæna villosa lately noticed at the cape by Dr. Smith, and described[4] as having the hair on the neck and body very long and shaggy, measuring in many places, but particularly about the sides and back, at least six inches; again, the thick shaggy covering on the anterior part on the body of the male lion, and the hairy coat of the camel (both of them inhabitants of the warmest climates), present analogies which show that no conclusive argument in proof that the Siberian elephant was the inhabitant of a cold climate can be drawn from the fact of the skin of the frozen carcass at the mouth of the Lena having been covered with coarse hair and wool; but even if it were proved that the climate of the arctic regions was the same both before and after the extirpation of these animals, still must we refer to some great catastrophe to account for the fact of their universal extirpation, and from those who deny the occurrence of such catastrophe, it may fairly be demanded why these extinct animals have not continued to live on to the present hour. It is vain to contend that they have been subdued and extirpated by man, since whatever may be conceded as possible with respect to Europe, it is in the highest degree improbable that he could have exercised such influence over the vast wilderness of northern Asia, and almost impossible that he could have done so in the boundless forests of North America. The analogy of the non-

[4] Vol. XV, Plate 2, page 463, Linn. Trans.

extirpation of the elephant and the rhinoceros on the continent and islands of India, where man has long been at least as far advanced in civilization, and much more populous than he can ever have been in the frozen wilds of Siberia, shows that he does not extirpate the living species of these genera in places where they are his fellow-tenants of the present surface of the earth. The same non-extirpation of the elephant and rhinoceros occurs also in the less civilized regions of Africa; still further, it may be contended, that if man had invaded the territories of the mammoth and its associates until he became the instrument of their extirpation, we should have found, ere now, some of the usual indications which man, even in his wildest state, must leave behind him; some few traces of savage utensils, arrows, knives, and other instruments of stone and bone, and the rudest pottery; or, at all events, some bones of man himself would, ere this, have been discovered amongst the numberless remains of the lost species which he had extirpated. It follows, therefore, from the absence of human bones and of works of art in the same deposits with the remains of mammoths, that man did not exist in these northern regions of the earth at or before the time in which the [p. 611] mammoths were destroyed; and the enormous accumulation of the wreck of mountains that has been mixed up with their remains points to some great aqueous revolution as the cause by which their sudden and total extirpation was effected. It cannot be contended, that like small and feeble species, they may have been destroyed by wild animals more powerful than themselves. The bulk and strength of the mammoth and rhinoceros, the two largest quadrupeds in the creation, render such an hypothesis utterly untenable.

"The state of the argument then respecting the former climate of the polar regions is nearly as follows: It is probable that in remote periods, when the earliest strata were deposited, the temperature of a great part of the northern hemisphere equalled or exceeded that of our modern tropics, and that it has been reduced to its present state by a series of successive changes. The evidence of this high temperature and of these changes consists in the regular and successive variations in the character of extinct plants and animals which we find buried one above another in the successive strata that compose the crust of the globe. These have in modern times been investigated with sufficient care and knowledge of the subject to render it almost certain that successive changes, from extreme to moderate heat, have taken place in those parts of the northern hemisphere which constitute central and southern Europe;

and although we are not yet enough acquainted with the details of the geology of the arctic regions to apply this argument to them with the same precision and to the same extent as to lower latitudes, still we have detached examples of organic remains in high latitudes sufficient to show the former existence of heat in the regions where they are found—a few detached spots within the Arctic Circle that can be shown to have been once the site of extensive coral reefs are as decisive in proof that the climate in these spots was warm at the time when these corals lived and grew into a reef, as, on the other hand, the carcass of a single elephant preserved in ice is decisive of the existence of continual and intense cold ever since the period at which it perished. We have for some time known that in and near Melville Island, and it has been ascertained by Captain Beechey's expedition, that at Cape Thompson, near Beering's Strait, there occur within the Arctic Circle extensive rocks of limestone containing many of the same fossil shells and fossil corals that abound in the carboniferous limestone of Derbyshire: the remains of fossil marine turtles also (chelonia radiata) have been ascertained by Professor Fischer to exist in Siberia. These are enough to show that the climate could not have been cold at the time and place when they were deposited; and the analogy of adjacent European latitudes renders it probable that the same cooling processes that were going on in them extended their influence to the polar regions also, producing successive reductions of temperature, accompanied by corresponding changes in the animal [p. 612] and vegetable creation, until the period arrived in which the elephant and rhinoceros inhabited nearly the entire surface of what are now the temperate and frigid zones of the northern hemisphere.

"Assuming then on such evidence as I have alluded to, the former high temperature of the Arctic Circle, and knowing from the investment in ice and preservation of the carcass of the mammoth, that this region was intensely cold at the time immediately succeeding its death, and has so continued to the present hour; the point on which we are most in want of decisive evidence is the temperature of the climate in which the mammoth lived. It is a violation of existing analogies to suppose that any extinct elephant or rhinoceros was more tolerant of cold than extinct corallines or turtles; and as this northern region of the earth seems to have undergone successive changes from heat to cold, so it is probable that the last of these changes was coincident with the extirpation of the mammoth. That this last change was sudden is shown by

the preservation of the carcass in ice: had it been gradual, it might have caused the extinction of the mammoth in the polar regions, but would afford no reason for its equal extirpation in lower latitudes; but if sudden and violent, and attended by a general inundation, the temperature preceding this catastrophe may have been warm, and that immediately succeeding it intensely cold; and the cause producing this change of climate may also have produced an inundation, sufficient to destroy and bury in its ruins the animals which then inhabited the surface of the earth."

[ZOOLOGY OF CAPTAIN BEECHEY'S VOYAGE TO THE PACIFIC AND BEERING'S STRAIT. London, 1839. Geology by Buckland from the notes of Lieutenant Belcher and Mr. Collie, pp. 159-180. Plate I is a plan of Eschscholtz Bay showing the various geological formations in colors, by Lieutenant Belcher.]

Kotzebue Sound [p. 169].—"The bounding shores of Kotzebue Sound for the most part rise by perpendicular cliffs, either directly from the waters or from a shelving beach. In some places the land is remarkably low, and only so much raised as to render the idea probable, that it is an alluvial formation, the result of the accumulated mud and sand brought down by large rivers and thrown up by the sea. The cliffs are in part abrupt and rocky; others are made up of falling masses of mud, sand, and ice. The first, or rocky cliffs, predominate to the southward of a line drawn from the northwest side of Eschscholtz Bay to the southeastern part of the Bay of Good Hope. The second, or diluvial cliffs, complete the remaining northeast side of the sound, and take in part of the south side of Eschscholtz Bay. Low grounds chiefly border the Bay of Good Hope, and form the land of and around Cape Espenberg. The history of these mud cliffs, and of the remarkable organic remains contained in them, has been given in vol. 1, Appendix [p. 173]. Cape Beaufort, viz., about 300 feet above the level of the sea. This cape seems to constitute a boundary between the hilly ranges above described to the southwest, and the low plains, intersected with lagoons and lakes, which extend to the northeast of it as far as the eye can reach [p. 174]. These plains are the commencement of a country of diluvial formation, that extends from Cape Beaufort to Icy Cape, Reindeer Station, and Wainwright Inlet. Beyond that Mr. Elson has described the coast and country to be a continuation of the same formations, and at Cape Smyth, near his extreme point, in lat. 71° 13′ N., long. 156° 45′ W., he observed icy cliffs presenting their fronts under the like circumstances as at Cape Blossom and in Eschscholtz Bay."

[NARRATIVE OF THE VOYAGE OF THE H. M. S. HERALD DURING THE YEARS 1845-51, UNDER CAPTAIN HENRY KELLETT, R. N. By Berthold Seemann. In two volumes. London, 1853, Vol. II, p. 33. The Ice-cliffs of Eschscholtz Bay—Their Formation and Fossil Remains—Sir John Richardson's views on them.]

"The ice-cliffs[6] of Eschscholtz Bay, in Kotzebue Sound, well deserve attention. They extend along the southern side of the bay, east and west, from Elephant Point to Eschscholtz Point; they are from forty to ninety feet high, and consist of three distinct layers. The lower layer is ice, the central clay, containing fossils, and the uppermost peat. Partly from the action of the waves, partly the thawing of the ice, that side of the cliffs facing the sea is cut perpendicularly, and presents a clear view of the internal structure of the formation.

"The ice, or lower layer, as far as it can be seen above the ground, is from twenty to fifty feet thick, but is every year decreasing. In the months of July, August, and September a considerable quantity melts, which causes the downfall of the two upper layers, and gives [p. 34] the whole a very confused aspect, by mixing together peat, clay, plants, bones, and ice in a most disorderly manner. The ice was thought by some of the earlier visitors to be only a superficial coating; but this supposition was disproved in 1849, when enormous portions were found to have separated from the main body, testifying beyond a doubt that it formed part of a solid iceberg. Others, who comprehended the real nature of this lower layer, endeavored to explain its presence by assuming that the water of the surface penetrated through the peat and clay, gradually accumulated, changed into a mass of ice, and thus caused the rising of the cliffs. This hypothesis at first sight appears plausible, but if examined it falls to the ground. In temperate climates we often find moorlands rising, like a sponge, in consequence of the mass of water which has accumulated in them; in Kotzebue Sound, however, where the soil is always frozen at a depth of two or three feet from the surface, no water can possibly sink to the depth of several fathoms, and consequently no rising can take place.

"The second or central layer varies in thickness from two to twenty feet, and consists of alluvial clay intermingled with gravel, sand, and fossil bones, the whole emitting the peculiar smell common in burial-places. In one spot was found some long black hair, together with a quantity of light brown dust, evidently decomposed

[6] For a view of these cliffs see Plate I of the "Botany of the Voyage of H. M. S. Herald."

animal matter. The fossils are sometimes of great size. In 1848 we collected eight tusks of the antediluvian elephant, the largest of which, though broken at the point, was eleven feet six inches long, one foot nine [p. 35] inches in circumference at the base, and weighed 243 lbs. Molar teeth, thigh-bones, ribs, and other fragments of this gigantic animal, and a great number of horse and deer bones, were disinterred. The species found in these cliffs are the mammoth (*Elephas primigenius*), the fossil horse (*Equus fossilis*), the moose-deer (*Cervus Alces*), the rein-deer (*Cervus Tarandus*), fossil musk-ox (*Ovibos moschatus*), *Ovibos maximus,* fossil bison (*Bison priscus ?*), the heavy-horned fossil bison (*Bison crassicornis*), and the big-horn (*Ovis montana*).

"The uppermost layer, or surface, is from two to five feet thick. consisting of peat, entirely destitute of fossils. It bears the kind of vegetation to which it owes its existence—plants peculiar to moorlands. Among them many mosses, lichens, sedges, and several *Ericaceæ* and willows may be recognized, the occurrence of which demonstrates the possibility of the growth of plants in a soil frozen beneath, a fact formerly much disputed.

"As the ice could not have been formed by water percolating through the clay and afterwards becoming frozen, it is natural to conclude that it was in its present site previous to the arrival of the clay. This conclusion is strengthened by the evidence afforded by the clay itself, for the fossils are solely confined to that layer. If these were indiscriminately distributed, we might be led to suppose that the whole had undergone the same revolution; such not being the case, we are forced to believe that the clay with its fossils arrived after the ice had been firmly established, and, as these fossils belong to the antediluvian period, the ice must be very old.

"Dr. Richardson, with that accuracy for which he [p. 36] is so distinguished, has in the 'Zoology of the Voyage of H. M. S. Herald' described the bones collected by us, and prefaced his description by the following philosophical observations:

[THE ZOOLOGY OF THE VOYAGE OF H. M. S. HERALD, UNDER CAPTAIN HENRY KELLETT, DURING THE YEARS OF 1845-51. Fossil mammals. By Sir John Richardson. Printed in 1852, but not published until 1854. Observations on the Fossil Bone Deposit in Eschscholtz Bay, pp. 1-8.]

"The science of chemistry, as at present taught, justifies our belief that animal substances, when solidly frozen and kept steadily in a temperature below the freezing point, do not undergo putrefaction, and may be preserved without change for any conceivable

length of time. The depth to which, in northern countries, the summer thaw penetrates, varies with the nature of the soil, but, except in purely sandy and very porous beds, it nowhere exceeds two feet in American or Siberian lands lying within the Arctic Circle. The influence of the sun's rays is not perceptible at this depth until towards the close of summer, which occurs at a varying period of from five to ten weeks from the time that the surface of the earth was denuded of snow by the spring thaw. During the rest of the year, even in the forest lands, though not so long there as in the open barren grounds, or *tundras,* the soil is firmly and continuously bound up in frost. The thickness of the permanently frozen substratum is more or less influenced by its mineral structure, but is primarily dependent on the mean annual temperature of the air acting antagonistically to the interior heat of the earth. Unless the mean heat of the year in any given locality falls short of the freezing-point, there exists no perennial frozen substratum in that place. It is not necessary that we should here endeavor to trace the isothermal line of 32° Farh., as the reader may obtain a correct idea of its general course by consulting Baer's charts. It will suffice to say, that on the continent of America it passes some degrees to the southward of the sixtieth parallel of north latitude, and that while it undulates with the varying elevation of the interior, it has a general rise northwards in its course westerly.

"Where the permanently frozen subsoil exists it is a perfect ice-cellar, and preserves from destruction the bodies of animals completely enclosed in it. By its intervention entire carcasses of the extinct mammoth and tichorhine rhinoceros have been handed down in arctic Siberia from the drift period to our times, and, being exposed by land-slips, have revealed most interesting glimpses of the fauna of that remote epoch. Conjecture fails in assigning a chronological date to the time when the drift and bowlders were spread extensively over the northern hemisphere: the calculations that have been made of the ages occupied in the formation of subsequent alluvial deposits are founded on imperfect data; and we merely judge from the absence of works of art and of human bones, that the drift era must have been antecedent to the appearance of man upon earth, or at least to his multiplication within the geographical limits of the drift. Whatever may be our speculations concerning the mode in which the carcasses in question were enclosed in frozen gravel or mud, their preservation to present time in a fresh condition indicates that the climate was a rigorous one at the epoch of their entombment and has continued so ever since. Moreover, as

large carcasses could not, without decomposition, be conveyed from a distance by water, it is fair to conclude that the animals lived in the districts in which they are now found, or in their immediate neighborhood, and not, as some have supposed, in warmer and more distant regions.

"It seems also to us to be impossible that ice could have been the vehicle by which whole bodies or complete skeletons could have been brought from warmer parallels and deposited in the vast cemeteries of polar Siberia or in Eschscholtz Bay, for the simple reason that ice is not the product of these warmer countries. Nor does the difficulty seem less of explaining how such a group of pachyderms and ruminants could have been brought down by travelling glaciers from warmer southern valleys of mountain ranges no longer in existence, without admitting such extensive changes in the surface level of the district, as would confound all our ideas of the distribution of the drift, as we at present find it.

"It is easier to imagine that the animals whose osseous remains now engage our attention ranged while living on the shores of an icy sea, and that by some sudden deluge, or vast wave or succession of waves, they were swept from their pasture grounds. It is not necessary that we should here discuss the extent of this deluge, or inquire whether it covered simultaneously the north of Europe, Asia, and America; or operated by a succession of great waves or more local inundations. What more immediately concerns our subject is, to know that in the drift containing marine shells of existing species, and boulders borne far from their parent cliffs, we have evidence of diluvial action extending from the ultima Thule of the American polar sea to far southwards in the valley of the Mississippi.

"The identification of the fossil mammoth and rhinoceros of England and Europe with those of Siberia by the first of living comparative anatomists, might lead us to conclude that the same fauna inhabited the northern parts of the new and old world; but I think that we shall find evidence in the bones of bovine animals brought from Eschscholtz Bay, that an American type of ruminants was perceptible even in that early age.

"At the present time the moose-deer and mountain sheep inhabit districts of America suited to their habits up to the most northern limits of the continent; while the musk-ox and reindeer go beyond its shores to distant islands; and the arctic hare is a perennial resident of the most northern of these islands that have been visited, or up to the seventy-sixth parallel. Supposing the climate of North America, at a time just antecedent to the drift period, to have been

similar or nearly so to that which now exists, the habits and ranges of the ferine animals at the two dates, though the species differ, may have had a close analogy. The mammoth and other beasts that browsed on the twigs of willows or larger trees may have ranged as far north, at least in summer, as the moose-deer does now, or up to the seventieth parallel; and lichenivorous or herbivorous ruminants may have extended their spring migrations still further north: these journeys in quest of seclusion and more agreeable food being quite compatible with the co-existence of vast wandering herds of the same species in more southern lands, reaching even beyond the limits over which the drift has been traced, and where the final extinction of the entire race may be owing to causes operating in comparatively recent periods [p. 3].

"The St. Petersburg Transactions, and other works contain accounts of the circumstances attending the discovery of the entire carcases of a rhinoceros and of two mammoths in arctic Siberia; and one cannot avoid regretting that they were beyond the reach of competent naturalists, who might, by examining the contents of the stomach, the feet, external coverings, and other important parts, have revealed to us much of the habits of these ancient animals and of the nature of the country in which they lived. The inexhaustible deposits of organic remains in the Kotelnoi or New Siberian Archipelago lying off the Sviatoi Noss, may yet disclose some equally perfect carcases; and their exploration by a scientific expedition is a project that promises a rich return for the labour and expense of such an undertaking.

"In arctic America such remains have been discovered in a north-eastern corner alone, and as yet, bones, horns, and hair only have been obtained, without any fresh muscular fiber; but all the collectors describe the soil from which they were dug as exhaling a strong and disagreeable odour of decomposing animal matter, resembling that of a well-filled cemetery. In August, 1816, Kotzebue, Chamisso, and Eschscholtz discovered, in the bay which now bears the name of the last mentioned naturalist, some remarkable cliffs, situated a short way southwards of the Arctic Circle, and abounding, in the bones of mammoth, horses, oxen, and deer. The cliffs were described by their discoverers as pure icebergs one hundred feet high, and covered with soil on which ordinary arctic vegetation flourished. These novel circumstances excited strongly the attention of the scientific world; and when Captain Beechey and his accomplished surgeon Collie, ten years later, visited the same place, their best efforts were made to ascertain the true nature of the phenomenon. Dr. Buckland drew

up an account of the fossil remains then procured with illustrative plates, and Captain Beechey published a plan of the locality.[*]

"This plan comprises a nearly square section of country, having a width and length of about fourteen miles. The Buckland River, where it bends to the northward to fall into Eschscholtz Bay, flanks the district on its inland or eastern border. From the mouth of this river the coast-line trends nearly due west to Eschscholtz Bluff, and forms the south side of that bay; the shore for one-half of the way, or about seven miles, between the Bluff and Elephant Point, being composed of high icy cliffs, and for the remainder of the distance, or from Elephant Point to the river, the coast is low and slightly incurved. The west face of the land fronts Kotzebue Sound and is formed of slaty gneiss rocks, which terminate on the north at Eschscholtz Bluff, and ten or twelve miles to the southward the rocky eminences, taking an inland direction, are flanked by low marshy ground. A ridge of hills runs nearly parallel to the western shore at a distance of a mile and a quarter; and at their southern angle, where they bend inland, there stands still nearer the coast-line one of the loftiest bluffs, ascertained to be 640 feet high. From this corner the course of the range is south-easterly, the swampy country above mentioned running along its base. The banks of the Buckland are also represented as being high, if not hilly [p. 4], and they enclose, in conjunction with the range, a sloping valley or basin, drained by numerous rivulets, and opening to the north on the low coast eastward of Elephant Point. At the western entrance of the Buckland there is a minor display of frozen mud-cliffs; similar deposits exist also on its eastern bank as well as on the north shore of Eschscholtz Bay, likewise on various points of the coast between Bering's Strait and Point Barrow; but fossils have been detected only in Eschscholtz Bay, and on the banks of a few rivers that join Bering's Sea between it and Mount St. Elias.

[Richardson here gives extracts from the Narrative of Captain Beechey's voyage which I quote on a previous page and do not repeat here. Commenting upon the holes dug by Mr. Collie, three feet and five yards back from the edge of the cliff in which frozen earth was found at eleven and twenty inches depth, Richardson says in a footnote:] "Had the pits been sunk at a distance from the edge of the cliff to the depth of three or four yards, information of a more decided character would have been obtained; for the experiments do not of themselves prove satisfactorily that the frozen mud

[*] Zoology of Captain Beechey's Voyage, 1839.

which was reached so early in the summer as the end of July, at the depth of twenty-two inches, was not merely an unthawed layer of the superficial soil, reposing on pure ice at some distance below [p. 5].'[1]

" The above description of these remarkable cliffs has been quoted at length, as it is not only perfectly clear but also concise. The opinions of Captain Beechey and his officers respecting the origin of the ice-cliffs are discussed at considerable length in Dr. Buckland's paper, printed as an appendix to the Narrative of the Voyage.

" After an interval of twenty-four years, the recent voyage of the 'Herald' to this interesting spot has given a third opportunity of collecting fossil bones and examining the structure of these now far-famed cliffs. Captain Kellett, Berthold Seemann, Esq., and Dr. Goodridge, with the works of Kotzebue and Beechey in their hands, and an earnest desire to ascertain which of the conflicting opinions enunciated by these officers was most consistent with the facts, came to the conclusion, after a rigid investigation of the cliffs, that Kotzebue was correct in considering them to be icebergs. I have been favored with papers on the subject from each of the Herald's officers named above, and shall quote as fully from them as my limits allow, after premising a few general observations on the frozen cliffs of other parts of the arctic coast that have come under my personal observation.

" At Cape Maitland in Liverpool Bay, which forms the estuary of the Beghula River, and lies near the seventieth parallel, there are precipitous cliffs from eighty to one hundred feet high, composed of layers of black clay or loam enclosing many small waterworn pebbles and a few large boulders, with the exception of about eighteen inches of soil on the summit, which thaw as the summer advances, these cliffs present to the sea a constantly frozen wall, that crumbles annually [p. 6] under the action of the rays of a summer sun, but the fragments being carried away by the waves and prevented from accumulating, the perpendicular form of the cliff is preserved. Elsewhere on the coast cliffs equally vertical, but having a different exposure, were seen masked by a talus of snow, over which a coating of soil had been thrown by land-floods of melting snow pouring down from the inland slopes. The duration of these glacier-like snow-banks varies with circumstances. When the cliffs rise out of deep water, the ice on which the *talus* rests is broken up almost every summer, and the superincumbent mass, previously

[1] Richardson's comments on Beechey in a foot note.

consolidated by the percolation and freezing of water, floats away in form of an iceberg. In other situations the snow-cliffs remain for a series of years, with occasional augmentation marked by corresponding dirt-bands, and disappear only towards the close of a cycle of warm summers. In valleys having a northern exposure and sheltered by high hills from the sun's rays, the age of the snow may be considerable; but it is proper to say that though aged glaciers of this description do exist on the shores of Spitzbergen and Greenland, they are of very rare occurrence indeed on the continental coast of America. The ice-cliff of Eschscholtz Bay may have had an origin similar to that of the Greenland icebergs, and have been coated with soil by a single or by successive operations. I find it difficult, however, to account for the introduction of the fossil remains in such quantity, and can offer to the reader no conjecture on that point that is satisfactory even to myself. The excellent state of preservation of many of the bones, the recent decay of animal matter shown by the existing odor, quantities of hair found in contact with a mammoth's skull, the occurrence of the outer sheaths of bison horns, and the finding of vertebræ of bovine animals lying in their proper order of sequence, render it probable that entire carcases were there deposited and that congealation followed close upon their entombment. A gradual improvement of climate in modern times would appear to be necessary to account for the decay of the cliffs now in progress and the exposure of the bones. The shallowness of the water in Eschscholtz Bay, its narrowness, and its shelter from seaward pressure by Choris Peninsula and Chamisso Island, preclude the notion of icebergs coming with their cargoes from a distance having been forced up on the beach at that place. Neither is it more likely that the bones and diluvial matters were deposited in the estuary of Buckland's River and subsequently elevated by one of the earth waves by which geologists solve many of their difficulties, for ice could not subsist long as a flooring of warmer water. In short, further observations are still needed to form the foundations of a plausible theory.

"Dr. Goodridge describes the several cliffs in succession with much detail, beginning with that next Elephant Point and proceeding to the westward. His paper, though interesting throughout, is too long for transcription entire, and I shall therefore merely abstract the most material parts. He commences by stating that the unusually mild season had produced great landslides and exposed the structure of the several eminences forming the cliffs more extensively than in the year in which Captain Beechey visited them. Elephant

Point, forming a high promontory in 1826, had now subsided to a mere hillock by the thawing of the icy substratum, as Kotzebue predicted would happen. A pit was dug to some depth in the loose loamy soil of this hillock, formed by the debris of the ruined cliff, at a point where the thighbone of a mammoth protruded above the surface, without any ice being found; but on the east of the hill next in succession, a wedge-shaped landslip had left a triangular chasm, whose floor, elevated twenty feet above the beach, was bounded by walls fifty feet high, of pure transparent ice, and its interior angle, reaching thirty feet backwards from the face of the cliff, exhibited an alluvium seemingly undisturbed since it was originally deposited, and consisting of regular layers of 'drift' and peat covered with thick beds of broken sticks and vegetable matter, over which lay a stratum of red river-gravel, then a bed of argillaceous earth, capped by dry friable mould [p. 7] and surface peat, nourishing its peculiar vegetation of coarse grass, moss, lichens, etc. The icy side walls showed bands or layers considerably inclined, and testifying to their origin in drift snow; and the size of the sticks imbedded in the back walls of the chasm was greater than that of the stems of any of the bushes now growing in the neighboring ravines. It is to be recollected, however, that a short way up Buckland River, groves of spruce-fir are to be met with. A rivulet separates this hill from Elephant Point, and Dr. Goodridge found some of its slopes to be formed of semi-fluid mud, over which a man could not pass. On the *second* hill or cliff the depth of the soil varied with the unevenness of the ice on which it rested, from twenty feet to less than four, the soil being everywhere dry. On digging in one spot to the latter depth the surface of the ice was found to incline upwards in the direction of the hill, and the soil thrown out by the spade was so pulverulent that it was readily blown away by the wind. The *third* hill, which projected more boldly than the others, contained as far as explored, neither fossils nor ice, but seemed to be entirely composed of thick beds of peat, *logs* of wood, sticks, and vegetable matter, lying generally, but not regularly, in a horizontal position, resting on dry clay, and a bed of river gravel two feet thick. The *fourth* hill presented a *higher* and more extensive ice-cliff than any of the others, the ice having melted further back towards the center of the hill, and forming an even wall upwards of eighty feet in height. The *fifth* cliff or marked projection, in proceeding to the eastwards, appeared to have sunk bodily from the hill, forming its background, but had left behind it a few icy pillars and detached walls standing twenty feet above the surrounding level surface, and

still covered with from seven to ten feet of soil. Water was flowing copiously from these walls of ice, and they were transparent, without admixture of earth, while the soil which capped them was dry and friable. In the slope of this ruined cliff most of the fossils obtained on this occasion were found, a few small fragments only having been gathered from the soft mud at its foot. Some were collected from the surface of the slope, others were dug out at places where the tips of the tusks protruded through the soil.

"A deep valley through which a stream of water flows divides the *sixth* hill from the preceding one. Portions of this hill had subsided from the melting of the icy foundation, but in one part a solitary block of ice about twenty feet square rose above the surface, retaining a thin layer of soil on its summit. From the vicinity of this block the hill rose abruptly on all sides; its declivity descended without break to the beach, and its soil, except in the section that had sunk, did not appear to have been ever disturbed. The beach at this place was not composed of muddy detritus, like that which skirted the bases of the other cliffs. A mammoth tusk, having been noticed protruding above the surface of the hill, was traced downwards by digging to the depth of eight feet, and the skull with a quantity of hair and wool were found lying on a thin bed of gravel, beneath which was solid transparent ice. Enveloping the bones there was a bed of stiff clay several feet in thickness, and mixed with them a small quantity of sticks and vegetable matter. The superficial soil was loose and dry. A strong, pungent, unpleasant odor, like that of a newly opened grave in one of the crowded burial places of London, was felt on digging out the bones, and the same kind of smell, in a less degree, was perceptible in various other places where the cliffs had fallen. From the same pit out of which the mammoth's skull was dug the bones of some smaller animals (scapula, tibia, etc.) were taken and were duly labelled at the time, but in the course of their transfer from one public department to another, after reaching London, the labels have been lost, together with the specimens of the buried wood, gravel, and other matters found associated with the bones. Dr. Goodridge says that this eminence was the last examined, the approach of night having prevented the party from exploring another [p. 8] hill lying between it and Eschscholtz Bluff. That hill, however, was covered with luxuriant vegetation and no icy cliffs showed themselves.

"'On Choris Peninsula,' says the same gentleman, 'frozen soil was found at the depth of four feet at the end of September, after an unusually warm summer, and a cask full of flour deposited by

Captain Beechey in 1826, on Chamisso Island, was perfectly sound and fit for food when disinterred in 1848. It was disengaged with much difficulty from the frozen subsoil, and even the iron hoops of the cask were not rusted.' Dr. Goodridge appends to his paper some remarks on the annual waste of the ice-cliffs, and says that the bay is gradually filling up with the clay and soil which are precipitated into the sea on the melting of the ice on which they are reposed.

"Mr. Seemann reports the heads of porpoises and antlers of reindeer were found on the beach, having been deposited there by the natives.

"Captain Kellett, in answer to some queries I addressed to him, informed me that the ice-cliffs were in many places as much as sixty feet high, and of pure ice. He did not think that the ice extended inland as far as the range of hills, though on digging at a distance of a quarter of a mile from the edge of the cliff he found pure ice under a covering of between three or four feet of soil. In no instance were the fossils imbedded in the ice, but they generally lay on its surface, the large tusks showing through the soil. Many were gathered from the mud at the base of the cliffs, where they were exposed to the wash of the tide. In digging within the Arctic Circle to erect marks he always found the soil frozen at a depth of two feet.—Such are the chief particulars that I collected from the three officers quoted above. The naturalist who wishes to study the subject more deeply will find several opinions discussed in Dr. Buckland's Appendix to Captain Beechey's Voyage, as already mentioned."

[REPORT OF THE CRUISE OF THE U. S. REVENUE STEAMER CORWIN IN THE ARCTIC OCEAN IN 1880. By Captain C. L. Hooper. Published in 1881, by Treasury Department.]

"Glacial Formations and Fossils at Elephant Point

"On the 16th (July, 1880), I visited Elephant Point, about fifteen miles distant, on Eschscholtz Bay, near the mouth of the Buckland River. This place is remarkable for a singular ice formation, which Kotzebue described as 'a glacier covered with soil six inches thick, producing the most luxuriant grass, and containing abundance of mammoth bones.' Captain Beechey, of the Royal Navy, while cruising in the Arctic in 1826-27, claims to have fully established the fact that Kotzebue was mistaken; that what he called a 'glacier' was occasioned either by the water from the thawing ice and snow trickling down the surface of the earthy cliff

from above, or by the snow being banked up against the cliff in winter, and afterwards converted into ice by alternate thawing and freezing, producing the appearance which deceived the Russians.

"The cliffs in which this singular formation is found begin half a mile from the eastern extremity of Elephant Point and extend westward, nearly in a direct line, about five miles. They are from forty to one hundred and fifty feet in height, and rise inland to rounded hills from two hundred to three hundred feet high.

"The eastern part, where the ice formation is found, is nearly perpendicular for about one mile; from thence to the western extremity, it is slightly inclined and intersected by small valleys and streams of water.

"I examined the ice, and, although not fully convinced that Beechey has given the true explanation of it, I do not think it is a glacial formation. In several places where water has run down over the face of the cliff, in small streams, from the melting snow above, I found holes melted at least thirty feet deep, showing solid walls of clear ice.

"I also ascended the cliff and dug down from the top in several places, and always came to solid ice, after digging through frozen earth for a few feet. I searched the face of the cliff for fossil remains, but found none, either in the ice or in the soil above it. I was more fortunate, however, on the beach below, after the tide fell. There I found a large number of mammoth bones and tusks, and some smaller bones belonging probably to the 'Aurock' (Bison) and musk-ox."

[EXTRACT FROM A REPORT TO C. P. PATTERSON, SUPT. COAST AND GEODETIC SURVEY. By W. H. Dall, Assistant in charge of schooner "Yukon," employed on the coast of Alaska. American Journal of Science, 1881, Vol. 21, p. 106.]

"On the 2d of September (1880), the weather being unsuitable for observations, I took the large boat and crew and crossed the bay toward Elephant Point, the site of the extraordinary ice formation, first observed by Kotzebue and afterward reported on by Beechey and Seemann.

"We landed on a small, low point near some old huts, and proceeded along the beach about a mile, the banks being chiefly composed of volcanic breccia or a slaty gneissoid rock. They rose fifteen to fifty feet in height above the sea, rising inland to hilly slopes, without peaks and probably not attaining more than three or four hundred feet anywhere in the vicinity.

"As we passed eastward along the beach, a change took place

in the character of the banks. They became lower and the rise inland was less. From reddish volcanic rock they changed to a grayish clay, containing much vegetable matter, which, in some places, was in strata in the clay, and in others indiscriminately mixed with it. Near the beginning of these clay banks, where they were quite low, not rising over twenty feet above the shore, we noticed one layer of sphagnum (bog moss) containing marl of fresh-water shells, belonging to the genera Pisidium, Valvata, etc. This layer was about six inches thick. The clay was of a very tough consistency, and, though wet, did not stick to or yield much under the feet. The sea breaks against the foot of these banks and undermines them, causing them to fall down, and the rough, irregular talus that results is mingled with turf and bushes from the surface above. A little farther on a perpendicular surface of ice was noticed in the face of the bank. It appeared to be solid and free from mixture of soil, except on the outside. The banks continued to increase slowly but regularly in height as we passed eastward. A little farther on another ice-face presented itself on a larger scale. This continues about two miles and a half to Elephant Point, where the high land turns abruptly to the south and west, and we followed it no farther. The point itself is boggy and low, and is continued from the foot of the high land, perhaps half a mile to the eastward, forming the northwest headland to a shallow bay of considerable extent.

" To return to the ' cliffs ': these for a considerable distance were double; that is, there was an ice-face exposed near the beach with a small talus in front of it, and covered with a coating of soil two or three feet thick, on which luxuriant vegetation was growing. All this might be thirty feet in height. On climbing to the brow of this bank, the rise from that brow proved to be broken, hummocky and full of crevices and holes; in fact, a second talus on a larger scale, ascending to the foot of a second ice-face, above which was a layer of soil one to three feet thick covered with herbage.

" The brow of this second bluff we estimated at eighty feet or more above the sea. Thence the land rose slowly and gradually to a rounded ridge, reaching the height of three or four hundred feet only, at a distance of several miles from the sea, with its axis in a north-and-south direction, a low valley west from it, the shallow bay at Elephant Point east from it, and its northern end abutting in the cliffs above described on the southern shore of Eschscholtz Bay. There were no mountains or other high land about this ridge in any direction, all the surface around was lower than the ridge itself.

"About half a mile from the sea, on the highest part of the ridge, perhaps two hundred and fifty feet above high-water mark, at a depth of a foot, we came to a solidly frozen stratum, consisting chiefly of bog moss and vegetable mould, but containing good-sized lumps of clear ice. There seemed no reason to doubt that an extension of the digging would have brought us to solid, clear ice, such as was visible at the face of the bluff below. That is to say, it appeared that the ridge itself, two miles wide and two hundred and fifty feet high, was chiefly composed of solid ice overlaid with clay and vegetable mould. It was noticeable that there was much less clay over the top of the upper ice-face than was visible over the lower one, or over the single face when there was but one and the land and bluff were low near the beach. There also seemed to be less vegetable matter. Near the beach six or eight feet of clay were observed in some places, without counting what might be considered as talus matter from further up the hillside. In one place only did we notice a little fine, reddish gravel, and nowhere in the talus or strata any stones.

"The ice-face near the beach was not uniform. In many places it was covered with clay to the water's edge. In others, where the bank was less than ten feet high, the turf had bent without breaking after being undermined, and presented a mossy and herbaceous front, curving over quite to high-water mark.

"The ice in general had a semi-stratified appearance, as if it still retained the horizontal plane in which it originally congealed. The surface was always soiled by dirty water from the earth above. This dirt was, however, merely superficial. The outer inch or two of the ice seemed granular, like compacted hail, and was sometimes whitish. The inside was solid and transparent, or slightly yellow-tinged, like peat water, but never greenish or bluish like glacier ice. But in many places the ice presented the aspect of immense cakes or fragments, irregularly disposed, over which it appeared as if the clay, etc., had been deposited. Small pinnacles of ice ran up into the clay in some places, and, above, holes were seen in the face of the clay-bank, where it looked as if a detached fragment of ice had been and had been melted out, leaving its mold in the clay quite perfect.

"In other places the ice was penetrated with deep holes, into which the clay and vegetable matter had been deposited in layers, and which (the ice melting away from around them) appeared as clay and muck cylinders on the ice-face. Large rounded holes or excavations of irregular form had evidently existed on the top of

the ice before the clay, etc., had been deposited. These were usually filled with a finer-grained deposit of clay with less vegetable matter, and the layers were waved, as if the deposit had been affected by current action while going on.

"In these places was noticed, especially, the most unexpected fact connected with the whole formation, namely, a strong peculiar smell, as of rotting animal matter, burnt leather, and stable manure combined. This odor was not confined to the spots above mentioned, and was not quite the same at all places, but had the same general character wherever it was noticed. A large part of the clay had no particular smell. At the places where the odor was strongest, it was observed to emanate particularly from darker, pasty spots in the clay (though permeating elsewhere), leading to the supposition that these might be remains of the soft parts of the mammoth and other animals, whose bones are daily washed out by the sea from the clay talus.

"At or near these spots, where the odor was strongest, a rusty, red lichen, or lichen-like fungus, grew on the wet clay of the talus in extensive patches. Some of these, of the bad smelling deposit, and as many bones of the mammoth, fossil buffalo, etc., as we could carry were secured. These included a mammoth tusk, with both ends gone, but still five and a half feet long and six inches in diameter, which I shall forward to the office. Dwarf birches, alders, seven or eight feet high, with stems three inches in diameter, and a luxuriant growth of herbage, including numerous very toothsome berries, grew with the roots less than a foot from perpetual solid ice.

"The formation of the surrounding country shows no high land or rocky hills, from which a glacier might have been derived and then covered with debris from their sides. The continuity of the mossy surface showed that the ice must be quite destitute of motion, and the circumstances appeared to point to one conclusion, that there is here a ridge of solid ice, rising several hundred feet above the sea, and higher than any of the land about it, and older than the mammoth and fossil horse; this ice taking upon itself the functions of a regular stratified rock. The formation, though visited before, has not hitherto been intelligibly described from a geological standpoint. Though many facts may remain to be investigated, and whatever be the conclusions as to its origin and mode of preservation, it certainly remains one of the most wonderful and puzzling geological phenomena in existence.

"On the 3d of September we sailed from Chamisso Harbor for Bering Strait. * * *"

The above account has been reprinted by Mr. Dall in the following: Bulletin of the U. S. Geol. Survey No. 84, 1892, pp. 261-263, pl. III.

"Respecting the strong, peculiar odor it is remarked in a footnote on page 262. 'This phenomenon was observed by Kotzebue, Beechey, and the Herald party, and lends further probability to the view that the animals were mired in the clay and thus met their death. Since, if the clay contained merely the accumulated bones of animals which had died and decayed on the surface of the ground, it is unlikely that so much animal matter would have been hermetically sealed in the clay and kept on ice to offend the nostrils of later visitors. On the other hand, if the ice had not been present and the temperature not kept so low it is unlikely, even in the clay, if animal matter could have been preserved for such an enormous period of time in a condition to give out so ammoniacal a stench. All the circumstances point toward the view that the ice preceded and subsequently co-existed with animals whose remains are now in its vicinity.'"

On page 263 Dall continues: "From the character of some of the bad-smelling deposit which was brought home and appeared to be exclusively composed of vegetable fiber finely comminuted, no doubt is felt that it represents dung of the mammoth or some other herbivorous animal which had been preserved in pockets on the surface of the ice where it was probably dropped, and by its dark color attracting the rays of the sun had sunk in, as is usual with dark objects dropped on an exposed ice surface."

The above discussion is repeated in a Report on Coal and Lignite of Alaska, by W. H. Dall, 17th Ann. Rep. of U. S. Geol. Survey, 1896, pp. 850-860. It is also referred to by Geikie[1] and Wright.[2]

[CRUISE OF THE REVENUE STEAMER CORWIN IN THE ARCTIC OCEAN IN 1881. Treasury Department Document No. 429. Washington, 1883.]

Muir, page 50, under head of Kotzebue Sound, remarks:

"A striking result of the airing and draining of the boggy tundra soil is shown on the ice-bluffs around Eschscholtz Bay, where it has been undermined by the melting of the ice on which it rests. In falling down the face of the ice-wall it is well shaken and rolled before it again comes to rest on terraced or gently sloping portions of the wall. The original vegetation of the tundra is thus de-

[1] The Great Ice Age, p. 664.

[2] Ice Age in North America, p. 33.

stroyed and tall grasses spring up on the fresh mellow ground as it accumulates from time to time, growing lush and rank, though in many places that we noted these new soil-beds are not more than a foot in depth, and lie on the solid ice."

[CRUISE OF THE U. S. REVENUE STEAMER CORWIN IN THE ARCTIC OCEAN IN 1881. Notes and Observations. By Captain C. L. Hooper. Treasury Department Document No. 601. Washington, 1884, pp. 79-82. With a text figure and two photographs.]

"At meridian of the 7th (Sept., 1881) we steamed over to Elephant Point, and came to anchor off the remarkable ice formation for which that place is celebrated. During the afternoon, accompanied by Messrs. Muir and Nelson, I went on shore to make an examination of the ice-cliff. In my report of the cruise of the Corwin in 1880, I made mention of this phenomenon:

"We spent several days in the vicinity of Elephant Point examining this and smaller ice formations which were discovered by our exploring parties from day to day; and although it is not claimed that all doubt is set at rest on this subject, we can safely assert that the large quantity of ice known to be here precludes the possibility of Beechey's explanation being the true one. Several hundred feet back from the edge of the cliff, at a place where a cave had occurred, caused by a small stream of running water, we found ice clear and solid. Ice appears in the face of the cliff in several places, but that discovered by Kotzebue is much the larger. This is about half a mile in length, and although its exact width is not known, it may safely be assumed to be not less than 300 feet. At about 400 feet back from the edge of the cliff the ground rises quite abruptly for 80 or 100 feet, and changes from the springy, mossy covering to a solid mass of earth and stones, and in several places large bosses of lichen-covered granite are exposed to view. Although but two feet beneath the surface, in no place is ice exposed on the top. The layer of mossy turf covers it as evenly as if laid on by man to protect it from the sun's rays. That it owes its existence now to this covering of moss I have no doubt, but its origin is not so clear. The grass referred to by Kotzebue grows along the edge of the cliff, and on all irregularities on the face of the ice where the soil from above has been undermined by the melting and falling over, has lodged. Considering its cold foundation and the shortness of the season, the growth of this grass is almost phenomenal. Specimens collected by us, growing on a mere handful of soil on the very face of the ice cliff, were 4 feet long, and when dry emitted the fragrant odor of fresh, new hay.

"Ice formations, in may respects similar to that at Elephant Point, occur in various parts of the northern regions, both in America and Siberia, wherever the frozen subsoil is found. This, according to Baer, is coincident with the isotherm of 32° Fahr., and its thickness increases in proportion as the mean temperature of the locality falls below that degree, its unlimited descent being checked by the interior heat of the earth. The extent and thickness of this frozen substratum, whether increasing or decreasing, and to what extent affected by local causes, are interesting subjects of inquiry. The thickness of the frozen mass has been measured in various parts of the north by boring. At Yakutz, Siberia, latitude about 62° and mean annual temperature 14°, the ground was found frozen to a depth of 382 feet. At Fort Simpson, on the Makenzie River, in nearly the same latitude as Yakutz, the mean annual temperature 25°, the frozen substratum was found to terminate at 17 feet from the surface; and at the close of the summer of 1837 the surface was found to be thawed to a depth of 11 feet, leaving only 6 feet of ground frozen. So far there appears nothing remarkable in the frozen substratum, it being controlled principally by the mean annual temperature of the locality and the internal heat of the earth. But why this frozen substratum should occur at certain places in the form of pure ice does not appear so clear. Whether these ice masses are fragments of the original ice sheet which overswept the polar regions, or are formed by the waters from the melting snow draining through the soft, light mosses which form the tundra, is a matter for scientific investigation. The presence of fossil remains of extinct species of animals in some of the Siberian ice masses points to the supposition that they have existed for many thousands of years, while some of the ice examined by us near Elephant Point showed unmistakable signs of having been formed by the melting snow filtering through the surface covering. The mass, though many feet in thickness, was composed of fine strata of ice, some pure and free from vegetable matter, and some so filled with decayed moss as to present more the appearance of frozen earth than ice. Upon being melted, however, it was found to contain but a small amount of vegetable matter, which had a rank, disagreeable taste and smell. This peculiarity was first attributed to the presence of animal matter, but, on examination with a microscope, revealed nothing but the remains of the same species of plants which formed the covering of the whole. A number of wedge-shaped pieces of ice found in the banks around Eschscholtz Bay were probably formed by a small crack in the ground filling with snow and ice, and continuing to enlarge under successive changes from freezing to thawing.

"While making investigations in the vicinity of Elephant Point, Mr. Nelson discovered the remains of a beaver dam at one end of the ice cliff, which gave rise to a great deal of speculation and discussion on board as to whether this particular body of ice was not originally a lake; and indeed, considering the habits of the beaver, it is difficult to account for the presence of this dam upon any other hypothesis. The dam was in a good state of preservation, the wood plainly showing the marks of the animals' teeth. It is readily seen how the land forming the north shore of the lake may have been washed away, and the ice exposed, by the water from the Buckland and other rivers, which discharge into Eschscholtz Bay. The shallowness of the bay, and the difference in the height of the cliff, on its opposite sides, show that a large amount of washing away has taken place. The moss and grass covering the surface of the ice are also easily accounted for. The germs are readily transported from the surrounding hills by small streams on the surface, snow-slides, high winds, etc. It is of a parasitic and very rapid growth, covering the most barren ground in a short time, even the dry hard surface of volcanic rock, and that it readily thrives on the ice is shown by the luxuriant growth found by us on every projecting point on the face of the ice-cliffs. Kotzebue was undoubtedly in error in supposing that the fossil remains of animals found in the vicinity were imbedded in the cliff. I examined them carefully each season and saw no signs of animal remains of any kind, while on shore; below high-water mark, we found them in abundance. They were not confined to the locality of the cliff, but extended each way as far as our investigation reached. They evidently came from the Buckland River, and were brought down by the drifting ice in the spring. The other rivers emptying into Kotzebue Sound contain large numbers of them, as also those emptying into Norton Sound. The natives assured us that large beds of these bones were to be found in the rivers but a few miles inland. Many of the tusks found in America up to the present time are very much decayed from exposure, but it is probable that by digging into the frozen earth they would be found in a perfect state. Our half-breed interpreter, Andrew, claimed to have seen large quantities in the bed of a stream which he discovered while on an overland trading voyage from Norton Sound to Kotzebue Sound the previous winter. He said he had taken a small piece on his sled and brought it down near the coast, but finding that it was overloading his dogs, he threw it off and left it. Some of our men accompanied him to the spot and found a portion of a small tusk in a perfect state of preservation.

The bones are found generally in the bed of rivers or in the alluvial deposits near their mouths. Many theories have been advanced to account for the accumulation of these bones, and by some writers it was supposed that the animals may have died in large numbers when in herds, but it is altogether likely that the remains were brought together by the action of the thousands of small streams of water formed by the melting snow, which everywhere flood the tundras in the spring. In this way they are carried to the larger rivers, and by them swept down, until by the widening of the river and the consequent decrease of the strength of the current they become stationary and are in time buried in the alluvium."

Hooper prolongs his text with a series of disconnected compiled remarks concerning the mammoth in general. Concerning Cape Blossom he remarks, pages 39: "It presents seaward a sheer cliff, which was described by Beechey as having an ice formation similar to that at Elephant Point. Although I visited this place several times during my two cruises, yet I saw no signs of ice against the face of the cliff like that at Elephant Point, which remains the same from year to year."

Fortunately this account may be materially supplemented from the personal notes of Mr. E. W. Nelson who has generously placed his private journal, with drawings, in the writer's hands.

September 7, 1881. "We steamed up opposite the bluff on Elephant Point. The water shoaled so we were forced to anchor in two and three quarters fathoms. The bluff was found to be one hundred and forty feet high and to be made up of ice and clay along its face for about three miles. The lower ice frequently presents a shelving projection under which the water at high tide (the rise and fall at the time of our visit being about three feet) had eaten fifteen to twenty feet. This exposure of ice slopes up and has its upper surface hidden by an inclined bank of sod and soil fallen from the terrace above. This sloping bank, covered with a luxuriant mass of vegetation, mainly grass two to four feet high interspersed with thrifty alder bushes, ends sharply against a more or less abruptly rising wall of ice five to twenty feet high forming the brow of the bluff. Over this upper ice is a layer from a foot to three or four feet of vegetable humus and peat upon which is a rank growth of grass. This surface ascends back and up gradually a few hundred yards or less to meet a slope rising at a much greater angle that extends up to the rounded summits of hills that continue into the interior.

"The accompanying sketch gives an idea of a section of the bluff.

"All along the shore in this locality a peculiar odor from the mass of decomposing vegetable matter exposed fills the air. This was more noticeable where the decaying vegetation in the clay was more abundant.

"Toward the eastern end of the face of the bluff on a slightly projecting point I found an old beaver house inbedded in the earth with two feet of vegetable humus on top of it. It was exposed in section by the crumbling of the bank.

"The base of the nest rested on an alder seven inches in diameter at the butt and the rest of the heap was composed of alder sticks one-half to three or four inches in diameter from six inches to five or six feet long. Nearly all of the smaller sticks had their bark eaten off and many still retained the marks of the teeth. All showed the

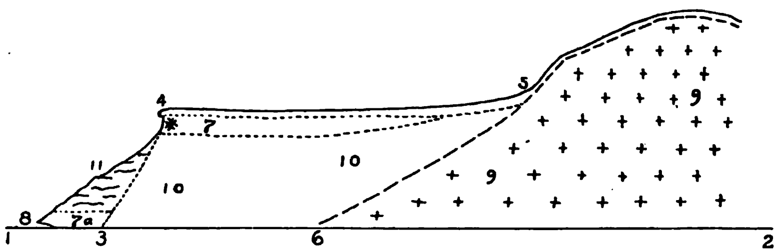


FIGURE 3.—Section of so-called "Ice-cliff" at Elephant Point, Kotzebue Sound, Alaska.

[After E. W. Nelson MS.]

1-2. Sea level.
3-4. Approximate surface of displacement along face of frozen silt bluffs.
4-5. Top of terrace 100-400 yards wide composed of about 4 feet of peat and humus overlying ice.
5-6. Approximate limit of Pleistocene basin.
7. Bed of dormant elevated ice with exposed front of 5-20 feet lying on top of silts (10) and overlaid by turf layer (4-5).
7a. Bed of ice that is probably derived from the upper bed (7). In its present position through displacement by the undermining of the sea.
8. Edge of ice (7a) being undermined in places by the sea.
9. Metamorphic rocks limiting the Pleistocene deposits and forming the interior ridges.
10. Frozen Pleistocene lacustrine silts 100 to 125 feet above sea level.
11. Loose talus slope along face of bluff, which being loosened up and aerated supports good growth of grass, etc.
⁕ Position of beaver nest.

teeth marks at each end. The entire mass was permanently frozen except for an inch or two along the exposed surface where it was slightly thawed. Only a few yards away on each side of the beaver nest, and apparently back of it, on about the same level, was ice apparently surrounding the mass of frozen earth upon which the nest

rested. I gathered some of the sticks from the nest. They were all alders, watersoaked, and soft enough to be easily picked to pieces with the finger nail."

2. ICE-CLIFFS ON THE KOBUK RIVER

[EXPLORATION OF THE KOWAK (KOBUK) RIVER. Science, Dec. 19, 1884, p. 551.]

Abstract of exploration on the Kowak or Kuak River of Alaska, made during the season of 1884 by a party under Lieut. Cantwell, U. S. steamer Corwin, Capt. Healy.

"July 12, 1884. At half past two p. m. a series of ice-cliffs, like those of Eschscholtz, was observed, composed of a solid mass of ice extending three-quarters of a mile along the left bank, covered by a thin layer of dark-colored earth, and rising to a height of a hundred and fifty feet. Trees were growing on the surface. Up to this point, and for some distance farther, not a single stone or pebble was to be seen, and the silence was frequently disturbed by the fall of large masses of the soft earthy banks undermined by the strong currents. * * * At half past four p. m. (July 24th) a remarkable clay bluff, three-quarters of a mile long and a hundred and fifty feet high, was reached on the left bank of the river. Quantities of mammoth tusks were observed in this clay and its debris where undermined by the stream."

[CRUISE OF THE REVENUE STEAMER CORWIN IN THE ARCTIC OCEAN IN THE YEAR 1885. Washington, 1887, p. 48. A Narrative Account of the Exploration of the Kowak River, Alaska. By Lieut. John C. Cantwell.]

"One of the most remarkable, in fact the only remarkable feature of the lower river, is the ice formation in the high black bluffs. The recent heavy rains had caused the river to rise to an unusual height, and I observed in many places where the erosion of the flood had exposed vast masses of ice, which had escaped my notice formerly. Change is the order of the day here, and it is no uncommon thing to see, soon after a flood or freshet in the river, masses of earth, upon which trees thirty or forty feet high have grown, suddenly break away and fall with a tremendous roar into the river. I obtained sketches and photographs of these broken bluffs, but no picture can adequately portray the feeling of utter desolation which this destructive work of the ever-rushing river conveys.

"The constant falling away of the soft earth, leaving the solid ice bare in many places, has given rise to many curious and fantastic formations.

"For miles along the river in this portion of its course these icy cliffs appear and disappear at regular intervals, so that it is observed that they recur in bends that are parallel with each other, which would seem to indicate that its existence is not due to deposits of ice by the river, else it would be in all of the bends, but that its presence is due to some other cause. If a straight line is drawn through the center of one of these ice-cliffs, and through the E.N.E. and W.S.W. points of the compass, it will not only touch all of the cliffs, but if extended to the sea will touch the coast at a point very near Elephant Point, on Eschscholtz Bay, where, it is well known, a peculiar ice formation in the bluffs has been observed and commented upon by numerous scientific men.

"Climbing to the top of one of these ice-cliffs, Mr. Townsend and I pushed our way through the dense thickets of willow and luxuriant growth of grass into the interior for about one mile, where we found a shallow lake about a mile in diameter, which I have no doubt had its origin in the mass of ice over which we had been travelling. It is almost inconceivable how such a rank vegetation can be sustained under such conditions. If we stood in one place any length of time the spongy moss became saturated, and soon a pool of dark-colored water made our position untenable.

"Besides the moss, berries, and stunted willows, clusters of spruce trees, some measuring six and eight inches in diameter, have taken root and grown in the thin strata of soil overlying the ice."

In the same report on pages 81-102 are Notes on the Natural History and Ethnology of Northern Alaska, by Charles H. Townsend, page 85. "Above the many-channeled delta the Kowak assumes a different character. High banks of old ice and clay appear, bearing a thin coat of surface soil, which supports the stunted arctic growth of white spruce. The banks, undermined by the melting of their ancient icy substratum, often slide in massive sections into the river, carrying a wide margin of forest with them. * * * Sometimes cavernous holes are excavated as the gritty ice disappears, and the overarching mass of earth hangs ready to fall when a few more hours exposure to the incessant arctic sunshine shall have set it free. These banks are too icy to be tunneled by kingfishers or bank swallows, consequently such birds are scarce along the lower river.

Page 89. "*Elephas.*—Tusks, teeth, and bones of the mammoth were seen in many of the villages on the Kowak River. The natives frequently carve ornaments and useful articles out of mammonths' tusks, and I saw some very large soup-ladles made out of this fossil ivory. At Cape Prince of Wales, where the Corwin anchored

a short time on her way north, several tusks and large bones of the mammoth were brought aboard for barter. * * * On August 28, 1885, at Schismareff Inlet, I found the front half of the skull of a mammoth lying on the open tundra, which was not fossilized in the least, being simply a mass of dry bone, firm and light. This is rather remarkable, considering the long extinction of the mammoth and the geologic and climatic changes which have since taken place in North America."

In the Amer. Geologist, Vol. VI, page 49, I. C. Russell publishes a letter from Lieut. J. C. Cantwell in answer to a request for further information regarding the ice-cliffs on Kowak River, Alaska.

"The river is navigable for a distance of 375 miles. At two points before reaching the headwaters, we encountered gorges where the width of the stream scarcely exceeds twenty yards and where the channel was filled with rough bowlders.

"Some seventy or eighty miles from the mouth is where we first observed the ice-cliffs mentioned in my official report. At this point the cliffs were from 125-150 feet high, gradually decreasing in height as we noted their recurrence on our way up stream, until they had entirely disappeared when we had reached the foot-hills of the first chain of mountains through which the river flows. The topography of the Kowak Valley in the vicinity of the ice-cliffs is characterized by undulating tundra plains, varied by patches of small spruce timber which, as a general rule, was most abundant along the banks of the stream. For about a mile there is exposed to view a solid mass of ice superposed by a layer of soft earth forming a uniform thickness of about six feet. In color the cliffs are dark brown. The ice is not clear and must have been formed from water holding in solution a large quantity of earthy matter. There is no apparent stratification. No gravel was seen. The shore line in front of the cliffs was marked by an accumulation of soft almost impalpable dust piled in heaps to a height of 15 or 20 feet. The dust piles were evidently the result of the melting of the ice during the summer, as the annual spring freshets sweeps everything before them.

"In the first place the ice is solid without fracture from top to bottom[*] and again there are numerous high sand and clay cliffs abutting on the river in situations exactly similar to those occupied by

[*] The writer does not believe Mr. Cantwell means to be understood that the cliffs are solid ice from the river level to a height of 150 feet, but that simply the ice deposit itself on top of the clays is solid, i. e., not stratified. His photographs support this interpretation.

the ice-cliffs, in which not a particle of ice is to be seen. All the ice-cliffs are located on the left or south bank of the river."

[NATIONAL GEOGRAPHIC MAGAZINE. Vol. VII, 1896, pp. 345-346. Ice-Cliffs on the Kowak River. By Lieut. J. C. Cantwell.]

" The Kowak River rises in the northwestern part of Alaska, and after a tortuous easterly course of about 550 miles, the greater portion of which is within the Arctic Circle, it flows into Hotham Inlet, a large body of fresh water opening into Kotzebue Sound. During the summer of 1884-85 it was my good fortune to visit this region and to make a reconnaissance of the stream from its mouth to its headwaters. Among the many novel and interesting features of the region, which had never previously been visited by white men, none were more striking than a remarkable series of ice-cliffs observed along the banks of the river about 80 miles from its mouth. These deposits of ice were first seen in some of the low silt banks of the delta, and it was supposed that they were the result of the spring freshets in the river forcing large masses of ice into the soft, yielding soil of the banks. But when on our emerging from the delta, and reaching the higher land of the interior we still found these ice deposits in the form of clifs, from 80 to 150 feet high, the theory of current formation had to be abandoned. The banks of the stream in the region where the ice-cliffs are found are not all filled with ice, and the water marks on those which are composed only of soil and rock show beyond question that the water has never reached a sufficiently high stage to have transported the ice to its present position.

" At two points the cliffs attain an altitude of over 150 feet, and one cliff measured by sextant angles showed 185 feet. The tops of all the cliffs were superposed by a layer of black, silt-like soil from 6 to 8 feet thick, and from this springs a luxuriant growth of mosses, grass, and the characteristic arctic shrubbery, consisting for the most part of willow, alder, and berry bushes, and a dense forest of spruce trees from 50 to 80 feet high and from 4 to 8 inches in diameter.

" Where the face of the cliffs was towards the south the upper portion of the formation would be found undergoing the process of destruction under the melting action of the sun's rays, while in other situations the erosion of the river current was constantly undermining the cliffs. Both of these destructive agents caused great masses of soil and tree-laden ice to become detached and fall into the stream. Where the retreating waters of spring had left these

masses of detached ice stranded on the adjacent beaches or bars, piles of soft dust almost entirely free from any gritty substance would be left as a monument to mark the spot where the ice had been melted by the summer sun. These small dust heaps are a characteristic feature of the region where the ice-cliffs are found and are entirely different in appearance from the gravel and sand heaps deposited in the same way by ice floated down from the upper river.

"An examination of the tops of the ice-cliffs was very difficult on account of the dense undergrowth and the thick carpet of moss, but on one we discovered a lake about a mile in diameter and situated some 500 yards from the face of the cliff. The water in this lake was fresh and clear, but upon being disturbed became exceedingly turbid, owing to the presence of a large quantity of fine, decayed vegetable matter on the bottom. A piece of the ice melted showed a residuum of fine, impalpable dust, which under a lens proved to be composed mainly of vegetable matter and, while fresh, emitted a very pungent, disagreeable odor.

"The country in this region is mostly rolling tundra plains, with innumerable small lakes, and streams, all of which are tributary to the larger river. There is no evidence of glacial action whatever, and it is not until the first mountain range is reached, a hundred miles further up-stream, that any rocks *in situ* are seen. Here and further inland more plainly are to be found beds of trap, which on examination shows to be a pronounced olivine diabase, with such minerals as hornblende, mica, feldspar, augite, etc., present. Other rock forms show unmistakable evidence of the eruptive agencies that have been at work in the formation of the upper river region. The formation of the remarkable ice-cliffs in the lower country is, however, a geological nut which the writer admits his inability to crack."

SMITHSONIAN MISCELLANEOUS COLLECTIONS

PART OF VOLUME XLIX

Hodgkins Fund

RESEARCHES ON THE ATTAINMENT OF VERY LOW TEMPERATURES

PART II.—FURTHER NOTES ON THE SELF INTENSIVE PROCESS FOR LIQUEFYING GASES

BY

MORRIS W. TRAVERS, D.Sc., F.R.S.
Professor of Chemistry in University College, Bristol, England

AND IN PART BY

A. G. C. GWYER, B.Sc., AND F. L. USHER

(No. 1652)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
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PART II.[1]—FURTHER NOTES ON THE SELF INTENSIVE PROCESS FOR LIQUEFYING GASES.

BY MORRIS W. TRAVERS, D.SC., F.R.S.
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I. INTRODUCTION.

In 1903 I submitted to the Smithsonian Institution an account of some researches on the liquefaction of air and hydrogen which I had carried out with the aid of a grant from the Hodgkins Fund. Since then, with the aid of a further grant from the same source, I have extended these investigations, and have obtained the results which are recorded in the following pages.

I may state at the outset that I have been obliged to confine my attention mainly to points of practical interest. After completing the first section of my work I began to make preparations for the complete investigation of the process of liquefying gases by the self-intensive process, and, in conjunction with Professor R. A. Lehfeldt, commenced a research on the determination of the Joule-Thomson effect for gases over a wide range of temperature and pressure. My removal to Bristol prevented me from continuing to participate in this work, which Professor Lehfeldt is now completing. My work was also considerably retarded by the fact that a compressor and air liquefier, which had been purchased by the Bristol University College shortly before my appointment, was found to be practically worthless, and only after the compressor had been completely reconstructed and a new air liquefier had been built, could any research be undertaken. With the means at my disposal this work occupied more than a year.

II. PREVIOUS RESULT.

Before going further I will make one or two remarks as to statements in my last paper. In calculating the quantity of the liquid pro-

[1] Part I was published in 1904 in Volume XLVI, Smithsonian Miscellaneous Collections, under the title: Researches on the Attainment of Very Low Temperature, by Morris W. Travers, D.Sc.

duced by a Hampson machine (*loc. cit.*, p. 13), I have certainly overestimated the "loss due to heat absorption by liquefier." This is put down as equivalent to 100 gms. of liquid per half-hour and from experiments with a Hampson machine fitted with a vacuum vessel surrounding the regenerator coil, so as to reduce the heat-absorption to an almost negligible quantity, it appears that this amount is more than twice as large as it should be. The theoretical yield of liquid air is probably nearer 7.5 per cent. for the conditions investigated, or 0.045 per cent. per atmosphere pressure.

The formula given on page 14 of the same paper indicates that the yield of liquid should be about 0.06 per cent. per atmosphere, a result which is also too high, and this is due to the fact that the value κ, which represents the Joule-Thomson effect in the equation, is not, in all probability, independent of the pressure.

I had intended to investigate the influence on the efficiency of the apparatus of the volume of air flowing through it, and of the initial pressure, temperature, etc. Since I commenced these experiments, however, Messrs. Bradley and Rowe (Physical Review, XIX., pp. 330 and 387) have carried out an investigation on these lines with a liquefier of the Hampson type, and as their work has been carried out in a most careful manner it is unnecessary for me to say more than that my own results are in complete agreement with theirs. The greater part of my work, however, refers to the relative behaviour of liquefiers of different construction.

III. The Efficiency of the Regenerator Coil in Self-Intensive Liquefiers.

In the various forms of my apparatus which I have described in my former communication to the Smithsonian Institution, the hydrogen has been cooled to the temperature of liquid air boiling *in vacuo* before entering the regenerator coil. The form and dimensions of the latter were determined solely from considerations based on experiments with the air liquefier, and it must be considered that my success with my first hydrogen liquefier was largely due to good fortune. In this machine the regenerator coil was made of copper pipe, 2 mm. inside and 3.5 mm. outside, wound as closely as possible in flat spirals to form a cylinder 180 mm. long and 50 mms. in diameter around a brass tube, which supported the expansion valve at its lower end.

In a second liquefier, which was built for Professor Anschütz of Bonn, by Brins Oxygen Company, the regenerator coil was of the same dimensions, but was constructed differently. It consisted of two copper tubes, of the same diameter, wound together, so that the cylinder, so formed, consisted ultimately of two coaxial coils which were connected in parallel, with the coil in the liquid air chamber above,

and with the valve below. The doubling of the coil was intended to diminish any tendency on the part of the pipe to become blocked with impurity separated from the gas, and to reduce friction in the pipe, and so increase the pressure at the expansion valve. These precautions are, as a matter of fact, totally unnecessary.

The results obtained with this liquefier were far from satisfactory, and a careful study of its behaviour showed that the fault lay entirely in the regenerator coil. It was evident that the preliminary cooling of the compressed gas was as complete as in the case of my first machine, probably even more so; but that the heat-interchange between the compressed and expanded hydrogen in the regenerator coil was unsatisfactory. Careful consideration of the problem soon led to an explanation of the inefficiency of the second regenerator coil, and it is this point I shall next discuss.

The phenomena connected with the interchange of heat between fluids in motion has been studied chiefly with a view to applying the results to steam boiler problems. Osborne, Reynolds, Stanton, and others have shown that when currents of water are made to flow in opposite directions through concentric tubes, the change of temperature is independent of the velocity of the streams, or that the heat-interchange is proportional to the relative velocities. The same remarks apply to the change of temperature and loss of heat by furnace gases in passing through boiler tubes; and to show how closely the phenomena of heat regeneration in gas liquefiers resembles those I have just referred to, it is sufficient to state that in the Hampson air liquefier the difference between the temperatures of the air which enters and leaves the apparatus shows the same difference of temperature even when the velocity of the stream of air passing through it is greatly increased.

It is also well known that the loss of heat that furnace gases undergo is considerably diminished if the absolute velocity of the gas be decreased. It can be shown, for instance, that by increasing the diameter of the tubes of an ordinary boiler, or by spacing the tubes of a water-tube boiler more widely the heat interchange between the gases and the water may be considerably reduced.

Were it possible to consider the phenomenon of heat interchange between two fluids moving in opposite directions on different sides of a conducting surface one of conduction of heat through the fluid, the study of it would be a comparatively simple matter. As a matter of fact, however, this is the case only when the fluids were travelling slowly, and on account of the low conductivity of gases the heat interchange is, under such circumstances, very small. When, however, the velocity of the fluid bears a certain relationship to the dimensions of the space through which it is flowing, the longitudinal components into

which we may theoretically divide the stream no longer form straight lines, but break up into eddies. As the result of this the heat passes more rapidly from the gas to the surface in contact with it, or *vice versa,* than it does when the " stream line " flow is maintained. It has been stated that for the efficient working of a boiler both the furnace gases and the water must " scrub " the surface separating them.

The formation of eddies in a fluid depends upon its velocity, viscosity, density and on the form of the aperture through which it is flowing. The greater the velocity when once the " critical velocity " is passed, the greater the tendency to form eddies, which also increase as the space through which the gas is flowing diminishes. Further, it is well known that when a gas strikes against a sharp edge or angular obstacle eddies are formed much more readily than when the stream of gas meets a curved surface.

The difference of the behaviour of the two regenerator coils referred to on page 2 may now be explained. The first coil consisted of a single copper tube, so that the velocity of the compressed gas flowing through it was twice as great as that of the gas in the second coil, each component of which was half the length. Further, since it was impossible to wind the double coil as closely as the single coil, the velocity of the expanded gas passing over the outside of the pipes was greater in the case of the first coil than in that of the second. As the tendency to form eddies in the gas increases with the velocity, particularly when the stream passes through narrow openings, such as exist between the flat spirals of the coil, it is not surprising that the efficiency of the second coil was lower than that of the first.

I was fortunately able to test this theory by means of trials carried out on two air liquefiers of the Hampson type. In one of these two copper tubes were wound together to form the regenerator coil, and in the other four copper pipes of the same diameter were similarly wound. The difference in the behaviour of the two liquefiers, which were otherwise identical, under exactly similar conditions was sufficiently marked to prove my point. The two-coil liquefier gave from 2 to 3 per cent. more liquid air than the four-coil liquefier, and whereas in the first case the difference between the temperatures of the air as it entered and left the apparatus was 0.4°, it rose in the second case to 1.4°.

It appeared, therefore, that in constructing regenerator coils the pipe should have as small an internal diameter as is possible, and that the coil should be closely wound. It is practically impossible to use copper tube of a diameter less than 2 mm. inside and 3.5 mm. outside on account of the mechanical difficulties which arise in joining the sections, and in winding the coil. The spacing of the spirals is theoretically limited by the fact that the glass vacuum-vessel enclosing the

coil can not be subjected to a back-pressure of over one atmosphere. I have, however, found it to be mechanically impossible to wind the spirals too closely.

It is practically impossible to further increase the rate at which the *compressed* gas loses its heat, but by means of an arrangement which I shall next describe I have under certain circumstances suc-

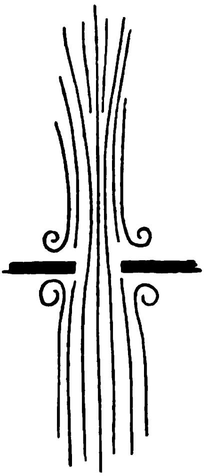


FIG. 1.—Eddies formed by passage of gas through orifice.

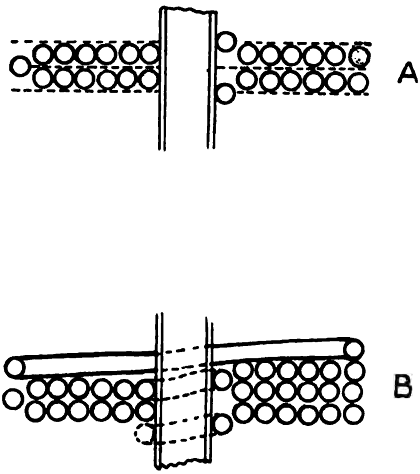


FIG. 2.—Regenerator coils.

ceeded in increasing the refrigerating efficiency of the expanded gas as it passes over the outside of the coils.

I have already referred to the fact that when a stream of gas passes across the edge of a plate at right angles to its path, or enters or leaves an orifice with square-cut edges, eddies are formed as in the figure 1. It occurred to me that by placing sheets of perforated vulcanized fibre between the horizontal spirals, which make up the coil, such eddies would be set up in the gas, and that the jets of gas passing through the holes would themselves form eddies both by their mutual action, and by impinging on the copper coils. Such an arrangement would be much more effective in overcoming the tendency of the gas to flow in streams, parted rather than broken up by the curved surface of the pipes. Further, the fibre being a highly non-conducting material would insulate the adjacent sections of the regenerator coil, and thereby increase its efficiency.

In the early part of the year 1904 I constructed two similar regenerator coils, each 20 cm. long and 7.2 cm. in diameter, wound about a tube 1 cm. in diameter, surrounding the valve rod. One of the coils,

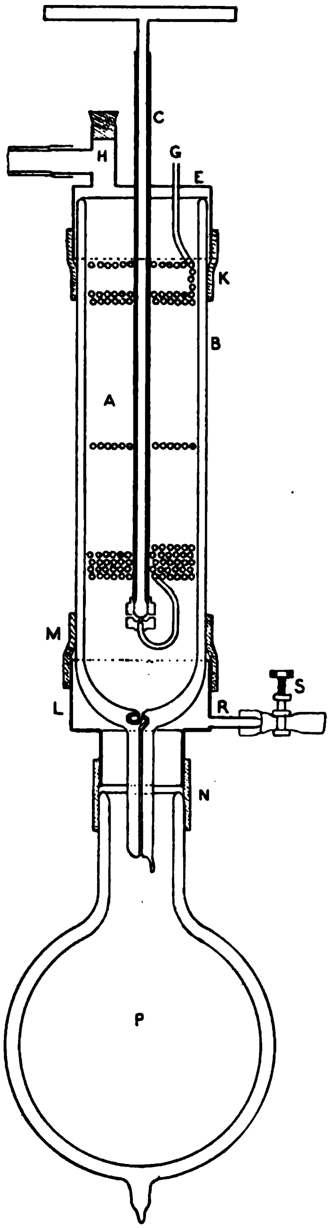


FIG. 3.—Apparatus for liquefying air.

A, had a disc of the vulcanized fibre between each horizontal helix, the other, *B*, had not (fig. 2). During the experiments the coil in use was placed inside a vacuum vessel, as in figure 3, arrangements being made for measuring the air passing through the apparatus, and

the air liquefied. To determine the temperature gradient in the coil the ends of thermo-electric junctions, carefully insulated, were placed at the top of the coil, near the valve, and at two points equi-distant from the end and well within the coil. Copper-constantan junctions were used; the potential difference between each of the junctions in the coil and a junction immersed in ice was measured by the usual potentiometer method; the results were interpreted with the aid of

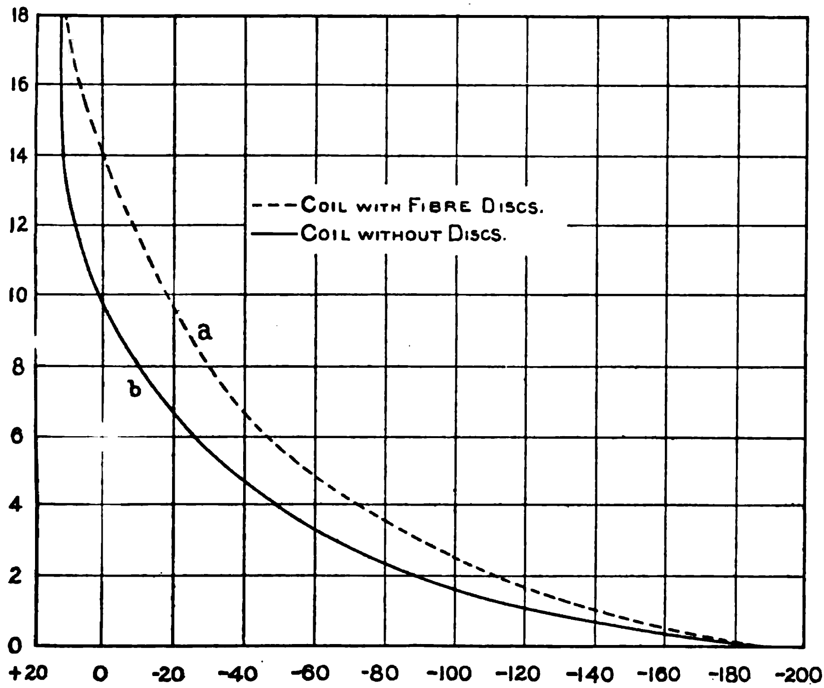


FIG. 4.—Temperature gradients.

comparative measurements of the electromotive force at temperatures corresponding to — 190°, — 78°, and 100° on the hydrogen scale.[1]

The exact arrangement of the apparatus is shown in figure 3. The regenerator coil *A* was completely enclosed within the vacuum vessel *B*, the space between the coil and the glass wall of the vessel being carefully filled with flannel, which was wound in thin strips round the former. The brass tube *C* surrounding the valve rod *D*, the supply pipe *G* from the compresser, and the tube *H* through which the expanded air escaped, were soldered into a brass cap *F* which was connected with the vacuum vessel by means of the rubber sleeve *K*. The

[1] Bradley and Hale (loc. cit.), working independently, obtained similar results for a Hampson machine with two coaxial coils. They used platinum resistance thermometers inserted between the coils.

wires from the thermo junctions, which are not shown in the figure, passed through a paraffined cork in the vertical opening of *H*, while a rubber tube connected with the horizontal opening led to a gas-meter, by means of which the volume of air was measured.

A brass reducing piece *L* and two rubber sleeves *M* and *N* connected the cylindrical vessel *B* with the vessel *P* in which the liquid air collected. The liquid ran directly from the nozzle of *B* into *P*, and to allow of the escape of the gaseous air which resulted in the evaporation of a little of the liquid, the pinchcock *S* could, if necessary, be opened from time to time.

The temperature gradients in the two coils are shown on the curve in figure 4. The curve *a* represents the gradient in the coil *A*, in which the perforated vulcanized discs had been inserted, and the curve *b* the gradient in the simple coil *B*.

The result of this part of my experiments is interesting. It will be observed that in the case of both coils the temperature gradient is at first very steep, but curiously enough the effect of introducing the fibre discs is, so far as the lower section of the coil is concerned, the reverse of what was looked for, the temperature gradient is rendered less steep, not more so. Over the upper section of the coil the fibre discs produce the desired effect, with the result that as a whole the coil *A* produces a slightly more effective heat interchange than the coil *B*.

The explanation of these facts is, I believe, as follows: Over the lower section of the coil, where the rate of heat interchange is normally very high, though the fibre discs may increase the eddying effect, they also shield the coils from close contact with gas, and hence their total effect is negative. Over the upper two-thirds of the coil, where the rate of heat interchange is low, the shielding factor is insignificant compared with the action of the discs in producing eddy motion, and the efficiency of the coil is increased.

TABLE I. RESULTS OF EXPERIMENTS WITH COILS A AND B.

Date.	Nature of Coil.	Mean Pressure.	Wt. of Air Passing Through Liquefier.	Wt. of Liquid Produced.	Wt. of Liquid Per Cent.	Liquid per Atm. Per Cent.
14/2	Simple.	170 atm.	10.54 kilo.	0.675 kilo.	6.5	0.038
16/2	"	174 "	9.77 "	0.680 "	7.0	0.040
18/2	With discs.	166 "	10.57 "	0.705 "	6.6	0.040
18/2	"	167 "	10.30 "	0.740 "	7.2	0.043
2/3	"	172 "	15.69 "	1.050 "	6.7	0.039
2/3	"	168 "	15.68 "	1.040 "	6.6	0.039

It is important to note that, as appears from Table I, the percentage of air liquefied, for quantities passing through the liquefier which vary as 2 is to 3, shows but slight variation. As might be

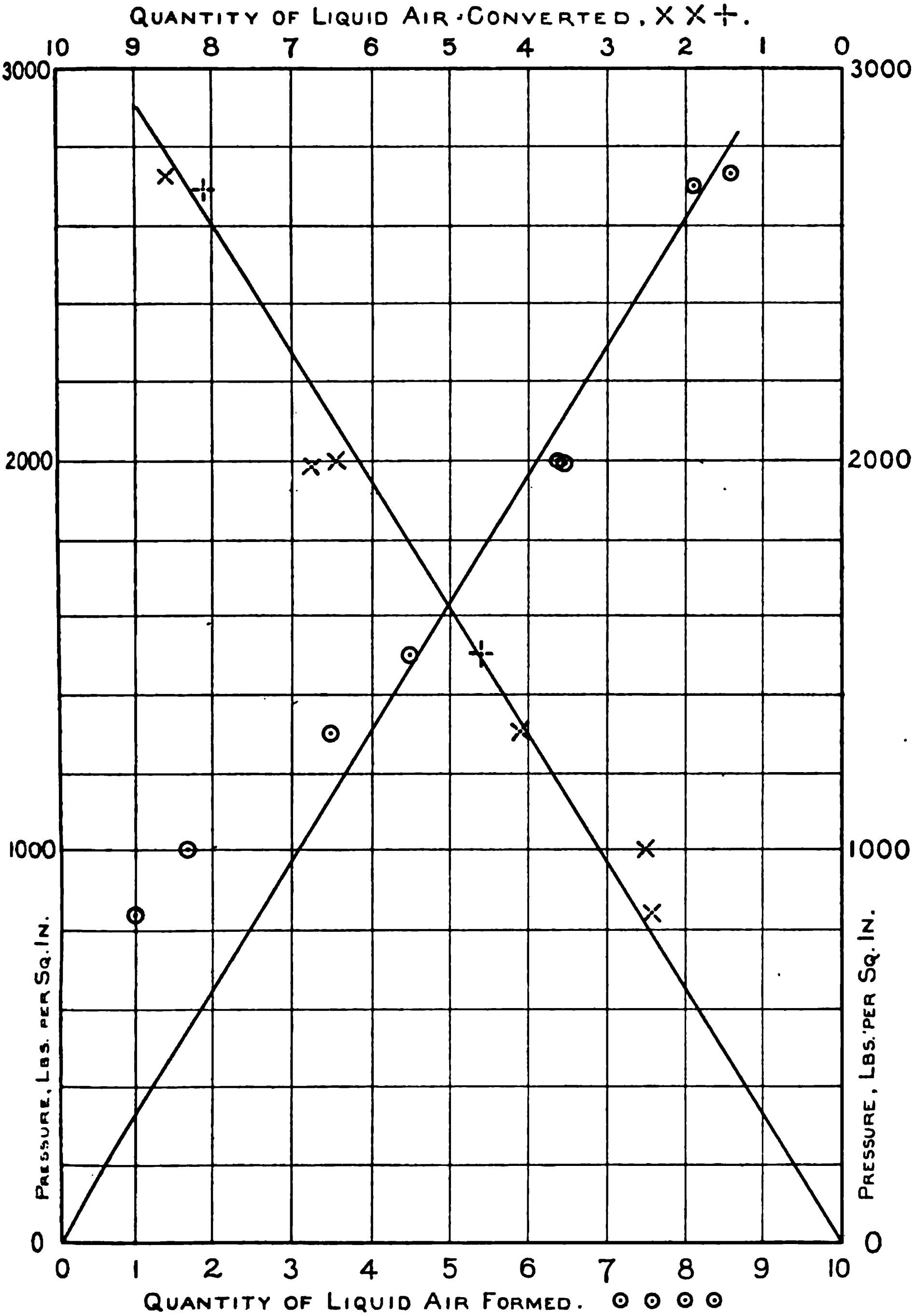


FIG. 5.—Reduction of Bradley and Rowe experimental results.

expected, the efficiency decreases slightly in proportion as the mass-flow of the air increases. The temperature measurements indicate, however, that the gradient in the lower part of the coil is practically independent of the quantity of air passing through it, though the temperature difference at the exit became slightly greater. Bradley and Rowe (*loc. cit.*) arrive at a similar result.

IV. Application of These Results to the Construction of a New Air Liquefier.

The result of these experiments seemed to show that the introduction of the vulcanized fibre discs increases the rate of heat interchange in the upper part of the coil, where the temperature difference between the two streams of gas is comparatively small, but is non-effective so far as the lower third at least is concerned.

The lower part of the liquefier which I constructed is arranged as in figure 3, but in place of the cap there is a metal cylinder filled with a coil constructed of two pipes coaxially. This part of the coil is 25 centimetres long and 10 centimetres in diameter. The cylinder enclosing it is secured to the vacuum vessel by means of a rubber sleeve, and is enclosed in a wooden casing filled with animal wool.

The results obtained with it have been quite satisfactory. The temperature difference at the inlet and outlet is smaller than can be measured, and the yield of liquid air is, within the limits of experimental error, as high as has been obtained with any liquefier.

Table II. Result of Experiment with New Air Liquefier.

Date.	Mean Pressure.	Wt. of Air Passing Through Liquefier.	Wt. of Liquid Produced.	Wt. of Liquid Per Cent.	Liquid per Atm. Per Cent.
22/9	170 atm.	15.75 kilo.	1.20 kilo.	7.61	0.045 [1]

V. The Effect of Initial Pressure on the Efficiency of a Liquefier.

I had intended to carry out experiments with a view to investigating the process from this point of view if results had not already been

Table III. Bradley and Rowe Eperiments.

Pressure Lbs. per Sq. In.	Liquid Per Cent.	Temperature Difference at Outlet.	Pressure Lbs. per Sq. In.	Liquid Per Cent.	Temperature Difference at Outlet.
A 2665	8.6	0.0°C	B 2650	8.1	0.0C
2000	6.4	0 25	1980	6.5	1.0
1500	4.5	0 50	1300	3.5	2.5
1000	1.7	3.25	.850	1.0	5.5

[1] Bradley and Rowe (*loc. cit.*) find 0.047 per atmosphere for their liquefier. The difference is well within the limits of experimental error.

published by Messrs. Bradley and Rowe. The results of their experiments are tabulated above.

They observe that when these results are plotted (figure 5 ⊙) the curve cuts the pressure axis at a point corresponding to a pressure between 700 and 800 atmospheres, below which no liquid would be formed. They remark that this may be in some measure due to the increase in the interchange temperature with fall of pressure, but make no attempt to connect the figures in the second and third columns.

Now if we take the heat of evaporation of liquid air to be 50 calories per gram, and its specific heat at constant pressure to be 0.237 calories per gram, we can assume that a fall of temperature of one degree in the escaping air is equivalent to the evaporation and warming up to the room temperature of $\frac{1}{x}$ of its mass of liquid air, where

$$(50 + 0.237 \times 200)x = (1 - x)0.237,$$

$$x = 0.25 \text{ per cent. per dyne.}$$

If then the interchange temperature were zero over all ranges of pressure the quantity of liquid air produced in the machine would be:

Pressure.	Correction.	Liquid Air Per Cent. (Corrected).	Pressure.	Correction.	Liquid Air Per Cent. (Corrected).
A 2665	0.00	8.6	B 1650	0 00	8.1
2000	0.05	6.45	1980	0.25	6.75
1500	0.10	4.6	1300	0.60	4.1
1000	0.80	2.5	850	1.40	2.4

In figure 5 the quantities of liquid air actually produced in the liquefier, and the quantities which would be produced if the difference between the temperature of the air as it enters and leaves the liquefier were zero, are plotted against the pressure. In neither case do the points lie on a straight line, but in the second case × they deviate from the straight line passing through the origin of the axis by amounts which are of the order of the errors of experiment.

I have not repeated these experiments myself, for I do not think that it would be possible without considerable elaboration to obtain more accurate results. Further, it appears to me that when the observations are corrected in the way I have suggested, they point to the conclusion under normal conditions of working the quantity of liquid air produced in the machine is very nearly a linear function of the temperature fall of pressure in the machine. If this is the case the production of liquid may be entirely attributed to Joule-Thomson cooling.

I have observed, however, that when the apparatus is worked at a

low pressure by opening the expansion valve wide, in which case there is a steady fall in pressure throughout the length of the coil, a very much smaller yield of liquid is obtained than when the valve is kept partially closed and supply of air is reduced. It appears that though a slight fall of pressure in the gas between the top of the coil and the expansion valve does not materially effect the working of the machine, it is a factor which cannot be neglected in estimating its efficiency.

VI. Application of the Perforated Discs to the Hydrogen Liquefier.

I now constructed a hydrogen liquefier, of which the regenerator coil *A*, with the perforated discs, formed part. This machine did not, however, yield satisfactory results, for though I obtained some liquid hydrogen by means of it, the yield was poor. I may add, however, that the liquefaction commenced very soon after the gas was first allowed to expand. Further, experiments conducted with compressed air, of which it is not necessary to give the details, pointed to the fact that the conduction of heat down the coil was considerably decreased by the introduction of the perforated discs.

The probable explanation of the behaviour of this coil is as follows. The effect of the discs in producing eddy currents increases the rate of heat interchange, so long as the temperature difference between the compressed and expanded gas is not very great, thus increasing the rate at which the coil cools down at the commencement of the experiment. When, however, the temperature of the expanded gas reaches the liquefaction point (20.5° abs.), the temperature of the compressed gas is still above the critical temperature, and we arrive at a condition similar to that which obtains in the lower part of the coil of an air liquefier. It appears then that the effect of the perforated discs in shielding the coils from contact with the expanded gas is greater than in increasing the eddying and thereby the rate of heat interchange.

VII. Final Form of Hydrogen Liquefier.

In reviewing my experiments with the hydrogen liquefier I am driven to the conclusion that the form of regenerator coil used in the construction of my first machine gave better results than any which I afterwards obtained. In this machine the coil was constructed of a single tube wound into a coil 150 mm. long and 50 mm. in diameter, the spaces between the components of each helix being as narrow as possible.

It appears that the small diameter of the coil and the closeness of the spacing are more effective in producing a rapid heat interchange,

by merely increasing the velocity of the flow of the expanded gas, than are any of the methods by which I have attempted to increase the surface exposed to the gas, or its tendency to form eddies over the surface of the coil. It is to this type that I have now reverted.

VIII. An Attempt to Employ a Metal Vacuum Vessel in the Liquefaction of Hydrogen.

As there appeared to be many obvious advantages in employing a metal vacuum vessel in place of the glass vessel which usually forms part of the apparatus, I determined to make one, and to carry out some experiments with it. The vessel was constructed of drawn brass tube with spun copper connection, as in the figure. After the parts had been soldered together the whole was silver-plated with the idea of rendering the metal absolutely non-porous. The vacuum vessel was secured by means of a flange and screws to a horizontal plate, which forms part of the annular space surrounding the liquid air chamber in the liquefier. A spiral copper tube connected the inside with the outside, and terminated below in a valve similar to that one used in the Hampson air liquefier.

The vacuum vessel was exhausted through a piece of fine copper tube, hard-soldered into the outer tube. When the exhaustion was complete this tube was melted in the oxyhydrogen flame and securely sealed. When the vacuum vessel was half filled with liquid air the outside did not become cold, but it was noticed that the liquid evaporated more quickly than from a glass vessel on account of the heat supplied to it by conduction down the inner wall.

An attempt to liquefy hydrogen with a machine fitted with the vacuum vessel proved a failure. This was probably due to the reason mentioned above, and also to the evaporation of the liquid in passing through the valve. Only a trace of liquid was collected, and the experiment was not repeated.

IX. On the Preparation of Hydrogen for Use with the Liquefier.

In my first memoir on the liquefaction of hydrogen I pointed out that the difficulty introduced by the presence of impurity in the gas was due rather to the separation of solid at the expansion valve than to the actual blocking of the coil. I suggested that this was probably due to the so-called " solvent " properties, which gases under high pressure and in the neighborhood of their critical temperature are known to possess.

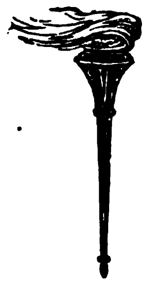
I have come to the conclusion that while some impurities are highly detrimental to the working of the apparatus, others are comparatively

innocuous. I have observed that when using an air liquefier, and using certain kinds of oil to lubricate the compressor, the vacuum vessel in which the liquid air is collected, when the latter is evaporated, contains a trace of oil.

After an experiment with a hydrogen liquefier, the moisture which remains in the vacuum vessel has often an oily smell. I have also often detected the odor of arsenuated hydrogen emitted from the solid condensed in the vacuum vessel as the apparatus becomes warm. I may say that I have always obtained the best results by using pure zinc, pure dilute sulphuric acid with a little copper sulphate, and taking care to employ a good lubricating oil on the working part of the compressor.

In June, 1903, I was invited to give a demonstration of the liquefaction of hydrogen before the Congress of Applied Chemistry in Berlin. I was unable to obtain a compressor, but was supplied with a number of cylinders of hydrogen, prepared by the electrolysis of calcium chloride solution, and compressed to 110 atmospheres. Six of the cylinders were at once connected with the liquefier and the expanded hydrogen was allowed to escape into the atmosphere.

Analysis of a sample of this gas showed that it contained 0.2 per cent. of oxygen. There was, however, no tendency for solid to form at the expansion valve and the result of my experiment was the most satisfactory that I ever reached.



SMITHSONIAN MISCELLANEOUS COLLECTIONS

PART OF VOLUME XLIX

Report on the Crustacea (Brachyura and Anomura) Collected by the North Pacific Exploring Expedition, 1853-1856

BY

WILLIAM STIMPSON

(No. 1717)

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INTRODUCTORY NOTE.

The North Pacific Exploring Expedition was sent out by the Navy Department under an appropriation from Congress in 1852, for "building or purchase of suitable vessels, and for prosecuting a survey and reconnaissance, for naval and commercial purposes, of such parts of Behring Straits, of the North Pacific Ocean, and the China seas, as are frequented by American whale-ships, and by trading vessels in their routes between the United States and China." The expedition set sail in June, 1853, and returned in 1856. Captain C. Ringgold, U. S. N., was placed in command, but, being recalled to the United States in 1854, he was superseded by Captain John Rodgers, U. S. N. William Stimpson acted as zoölogist. After leaving Norfolk the five vessels in service touched at Madeira, and then proceeded to Hongkong via the Cape of Good Hope. On this passage the sloop "Vincennes" and the brig "Porpoise" took the more southerly route to Van Diemens Land, thence through the Coral Seas, and by the Caroline, Ladrone, and Bashee Islands; while the steamer "John Hancock" and the other two vessels of the fleet traversed the straits of Sunda and Gaspar, the Carimata and Billeton passages, and the Sooloo Sea. Subsequently the expedition advanced northward, continuing work along the coasts of Japan and Kamchatka, in Bering Strait, on the coast of California, and at Tahiti, returning around the Cape of Good Hope.

Of the vast collections obtained, it was estimated that the Crustacea numbered 980 species.

A few years after his return to the United States, Dr. William Stimpson became director of the Chicago Academy of Sciences, and moved to that place nearly all of the invertebrate material obtained by the expedition and belonging to the United States Government. Several preliminary papers had been prepared and published by him[1] in the Proceedings of the Academy of Natural Sciences of Philadelphia, when the collections with notes and drawings were destroyed by the memorable fire, in 1871.[2] In a statement of losses sustained,[3] Dr.

[1] Prodromus descriptionis animalium evertebratorum, quæ in Expeditione ad Oceanum Pacificum Septentrionalem, a Republica Federata missa, Cadwaladaro Ringgold et Johanne Rodgers Ducibus, observavit et descripsit W. Stimpson.

[2] The above account is condensed from "Descriptive Catalogue of the collection illustrating the scientific investigation of the sea and fresh waters," by Richard Rathbun, published as Catalogue G of the Great International Fisheries Exhibition, London, 1883. Washington: Government Printing Office, 1883.

[3] According to Dr. Theodore Gill.

Stimpson enumerated the manuscript and drawings of the final report on the Crustacea Brachyura and Anomura. After his death, in 1872, however, this report was discovered at the Navy Department, and was sent to the Smithsonian Institution, where it has remained to the present time unpublished.[1]

In the meantime there are few students of the higher Crustacea who have not felt the need of more light on those rare genera and species known only from brief Latin diagnoses.

The following report has been treated as an historical document, and is published substantially as it was written by the author, the only additions being the references to his preliminary descriptions and the footnotes giving the current or accepted name where it differs from that used by Dr. Stimpson. It is hoped that the value of the descriptions will more than compensate for the antiquated nomenclature.

Numbers corresponding to those in the preliminary papers have been placed before each species for ready reference. The illustrations are from pencil drawings made, it is supposed, by Dr. Stimpson himself.

The many gaps in the illustrations and the absence from text or figures of any reference to the family Rhizopidæ are attributable to the withdrawal of these parts by Dr. Stimpson.

MARY J. RATHBUN.

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[1] Short extracts from the Maioidea were published in the Proceedings of the United States National Museum, xv, pp. 276–277, pl. XL, 1892; XVI, pp. 95–103, pl. VIII, 1893.

REPORT ON THE CRUSTACEA (BRACHYURA AND ANOMURA) COLLECTED BY THE NORTH PACIFIC EXPLORING EXPEDITION, 1853-1856

BY

WILLIAM STIMPSON

MAIOIDEA

MAIIDÆ

Genus LEPTOPUS Latreille

1. LEPTOPUS LONGIPES[1] (Herbst) Latreille

Cancer longipes HERBST.
Leptopus longipes LATREILLE; GUÉRIN, Icon., pl. x, fig. 3.
Egeria Herbstii MILNE EDWARDS, Hist. Nat. des Crust., I, 292.
Egeria longipes ADAMS and WHITE, Voy. Samarang, Crust., p. 7.

Among a large number of examples of this species collected by the expedition, there are two adult males which differ so much in the size and character of the chelopoda from the specimens ordinarily found, and those hitherto figured and described, that they might well be taken for a distinct species. The carapax of one of these specimens is 1 inch long and 0.85 inch broad. Proportion of breadth to length, 1:1.17. The chelopoda are large and robust, 1.8 inches in length. Hands much inflated; fingers gaping posteriorly; movable one with a large tooth at its inner base.

In nine-tenths of the male specimens taken, many of which are at least two-thirds as large as that above described, the hands are slender and weak, like those of the female; this (immature) form is that represented by Guérin's figure. In the sterile females, which occurred in equal numbers with the ordinary females and the males, the abdomen is flattened and only two-thirds as wide as the sternum.

In all of our specimens the præorbital tooth is very small; the orbits are interrupted above by two deep fissures, and below by one wide fissure divided into two by a small tooth. The projections of

[1] *Phalangipus longipes* (Linnæus).

the carapax are rather tubercles than spines. In color the body is light reddish above, mottled with white; below white; feet whitish, annulated with red. The figure given by Milne Edwards in the "Règne Animal" is less characteristic of our specimens than that of Guérin.

Dredged in the harbor of Hongkong, China, on a muddy bottom, at the depth of 6 fathoms.

Genus DOCLEA Leach

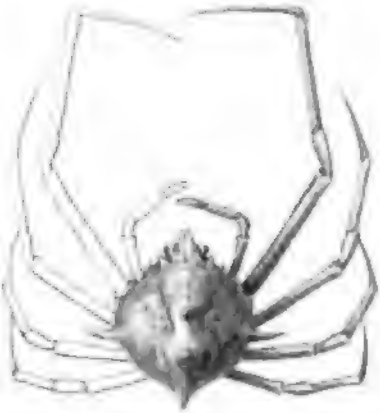
2. DOCLEA GRACILIPES Stimpson

PLATE I, FIG. 1

Doclea gracilipes STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 216 [23], 1857.

The species of the genus *Doclea* have great resemblance to each other in the shape and convexity of the carapax and in general appearance. The distinctions rest chiefly on the length of the feet and the proportional size of the lateral and posterior spines.

In *D. gracilipes* the body is covered with a short but dense villous coat, while the feet are less villous than is usual. The carapax, when this coating is removed, presents a deep suture or groove separating the stomachal, genital, and cardiac regions from the hepatic and branchial portions, and passing around behind the cardiac, separating this from the intestinal region. This groove is very deep where it passes the stomachal and genital regions. The median dorsal line is armed with six sharp tubercles, increasing in size posteriorly. The anterior three on the stomachal region are very small; one at the summit of the genital is larger; that on the cardiac becomes spiniform; and the posterior one, on the intestinal region, is still larger, though stout, blunt, and only one-tenth as long as the carapax. Of the four teeth usually described to be on the antero-lateral margin of the carapax, the anterior one belongs to the margin of the pterygostomian region, being at a lower level than the rest; in our species it is somewhat larger than the two following or intermediate ones; the posterior one, forming the extreme lateral spine, is very long (equaling in length more than one-sixth the width of the carapax), sharp, and curved forward. Besides the spines and teeth already mentioned, there are seven or eight slight tubercles on each side at the stomachal and branchial regions, only to be seen after the removal of the villous coat. The postero-lateral slopes are entirely smooth. The rostrum is but little longer than broad, slit for half its length, the horns being sharp. It is longitudinally



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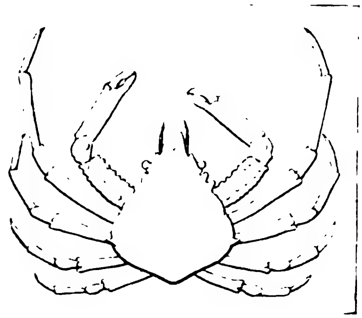

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CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

grooved above, as is usual in the genus. The arrangement of the orbits and antennæ is as usual. There is a small spine at the exterior base of the basal article of the external antennæ; another larger one at the anterior angle of the buccal area, and a small one between this latter and the large pterygostomian tooth. The pterygostomian region is depressed, but not channeled. There are two sharp tubercles on the sternum between the bases of the feet of the second pair. The feet generally are long and slender; those of the second pair more than twice as long as the carapax; chelopoda of very small size, slightly villous, with a few scattered long hairs. Finger and thumb denticulated within and contiguous for the terminal half their length. Abdomen of male seven-articulate, narrowing rather abruptly at the fourth segment; there is a protuberance on the second segment.

The body is of a dirty yellowish or hay color, mottled with black. Feet annulated with orange. Dimensions (spines included): Length of carapax, 0.95; width, 1.02; proportion, 1 : 1.07; length of a foot of the second pair, 2.2 inches.

It resembles *D. muricata* Edw., but has no visible spines on the branchial regions, and the feet of the second pair are more than twice as long as the body. The two lateral spines are much longer than in *D. rissonii*.

It was found in considerable numbers in the vicinity of Hongkong, China, occurring in 20 fathoms, gravelly mud, outside of the passages. and in 6 fathoms, mud, in some of the inner bays.

3. DOCLEA CANALIFERA Stimpson

PLATE I, FIG. 4

Doclea canalifera STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 217 [23], 1857.

This species is remarkable for the depressed pterygostomian channels just without the maxillipeds. The whole surface, with the exception of the tips of the tarsi and the fingers, is covered with a dense villous coat concealing all but a few of the more prominent spines. The interregional groove and the spines and tubercles of the carapax are in number and position nearly the same as in *D. gracilipes,* except that there is an intermediate tubercle between the genital and cardiac spines. The terminal posterior spine is very slender, somewhat curving upward, and in length a little more than one-tenth that of the carapax. The posterior of the antero-lateral spines or teeth is larger than the others, slender, and in length about

one-ninth the width of the carapax; the pterygostomian spine is the smallest of the four. The parts about the head are nearly the same as in *D. gracilipes,* except that the forks of the rostrum are rather more slenderly pointed, and there is no tooth between the pterygostomian tooth and that at the anterior corner of the buccal region. The external maxillipeds nearly reach the bases of the internal antennæ, thus almost entirely concealing the epistome. The pterygostomian region is depressed so as to form a deep channel leading forward from the afferent branchial openings. This channel is bounded externally by a high, sharp ridge fringed with long hairs. The feet are stout; those of the second pair shorter than twice the length of the carapax. Chelopoda more slender than the other feet and not as long as the carapax; the fingers slender, minutely denticulated within and contiguous throughout their length. Color brownish above and below; smooth tips of dactyli red.

A single specimen only (a male) of this species was taken; its dimensions (including the spines) are: Length of carapax, 1.65; width, 1.50; length of posterior spine, 0.17; of lateral spine, 0.17; length of a foot of second pair, 2.54 inches.

Taken in the dredge with a mass of Echini from a muddy bottom at the depth of 20 fathoms, off Tamtoo Island, coast of China, near Hongkong.

Genus CHIONŒCETES Kroyer

4. CHIONŒCETES BERINGIANUS[1] Stimpson

Chionœcetes behringianus STIMPSON, Proc. Bost. Soc. Nat. Hist., VI, 84, Feb., 1857; Jour. Bost. Soc. Nat. Hist., VI, p. 449, 1857.

Peloplastus pallasii GERSTÆCKER, Archiv für Naturgeschichte, XXII, 105, pl. 1, fig. 1.

Gerstæcker has given an excellent figure of this species in the Archiv für Naturgeschichte for 1856, but his paper does not appear to have been published before April, 1857; our name has, therefore, priority. The entomologist of Berlin does not seem to have been acquainted with Kroyer's genus *Chionœcetes,* to which the species certainly belongs; in fact, it is most closely allied to the type, *C. opilio.*

This species was found in Bering Strait and northward as far as the expedition penetrated, many specimens having been dredged by Captain Rodgers. It also occurred to the southward of the strait as far as Matwi Island. It is found only in deep water and

[1] *Chionœcetes opilio* (O. Fabricius).

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on bottoms more or less muddy. In a living state it was of a light brick-red color above, often iridescent; below yellowish-white; sides of feet shining white. The posterior feet are short. The dimensions of the carapax of a large female are: Length, 2.57; breadth, 2.72 inches.

In Gerstæcker's figure the surface of the carapax posteriorly and the upper sides of the ambulatory feet are represented as much more rugose than in any of our specimens.

Chionœcetes is evidently nearest allied to *Hyas,* although probably a higher form. In young specimens the resemblance to *Hyas* is easily noticed. *Hyas chilensis* should probably belong to it. It has considerable resemblance in general appearance to *Salacia* of the opposite extremity of the American continent, of which it may be considered the analogue.

Genus HYAS Leach

5. HYAS LATIFRONS[1] Stimpson

PLATE II.

Hyas coarctatus STIMPSON (non LEACH), Crust. and Echin. of the Pacific shores of N. America, Jour. Bost. Soc. Nat. Hist., VI, p. 450, 1857.

This species differs from *H. coarctatus,* of the North Atlantic, in the following characters, which are found to be constant upon examination of numerous specimens of both forms: The body is thicker and much broader anteriorly across the post-orbital apophyses; the angles are all more obtuse. The dorsal surface is marked with fewer tubercles, which are also much larger and more obtuse, most of them being rather swellings than warts. The rostrum is shorter and less acute; and the superior fissure of the orbit is always closed, its margins overlapping.

It is subject to considerable variation in some of its characters, particularly in the greater or less approximation of the forks of the rostrum, which may be so closely appressed against each other as to overlap, or may diverge so as to leave a narrow V-shaped space between. They diverge most in the young. The feet and inferior surface of the body are densely hirsute in some individuals and quite smooth in others. The color is a dusky brick-red above, whitish below. The dimensions of a male from the Arctic Ocean north of Bering Strait are: Length of carapax, 2.85; greatest breadth, 2.12;

[1] *Hyas coarctatus* Leach.

greatest postorbital breadth, 1.75; breadth at constriction, 1.59 inches.

This species was found by us in great numbers in all parts of the North Pacific Ocean north of the parallel of 50°. The following localities may be mentioned: Sea of Okhotsk; Awatska Bay and off Chepoonski Noss, coast of Kamchatka; off Matwi Island; in Bering Strait, and in the Arctic Ocean. It occurred on all kinds of bottom, from low-water mark to a depth of 50 fathoms or more. Among several hundred specimens of this species not one of *H. aranea* was found, although this latter species is said by Brandt to occur in the Sea of Okhotsk.

The specimens from the waters of Awatska Bay, which are somewhat brackish, do not differ from those taken in the open sea.

Brandt, in the Zoölogy of Middendorff's "Reise in den Sibiriens," part 1, page 79, describes a *Hyas* from the Sea of Okhotsk, which he considers a variety (*alutaceus*) of *H. coarctatus*. He states, however, that it differs from the Atlantic form in the somewhat more strongly granulated (stärker chagrinirte) upper surface of the carapax, in the broader posterior side of the body, and in the broader hands. These characters are certainly not those of our species, and for this reason we have not applied to the Pacific form the name *alutaceus*. In some of the larger specimens the surface is indeed granulated to some extent, particularly at the summits of the swellings; but specimens of ordinary size are always much smoother than any from the Atlantic. It is not impossible, therefore, that there is still another species in the North Pacific.

Genus MICROPISA Stimpson

Micropisa Stimpson, Proc. Acad. Nat. Sci. Phila., IX, p. 217 [24], 1857.

It has been found necessary to institute a genus for the reception of a small *Pisa*-like crustacean which was taken in considerable numbers at the Cape de Verde Islands. It has a short and broad, ovate carapax and flattened rostrum. The orbits are much less complete than in *Pisa*, and have a single fissure above. It resembles *Scyra* in many respects, but the external antennæ are not concealed beneath the rostrum. The outer maxillipeds resemble somewhat those of *Pisa;* but the outer angle of the almost heart-shaped third joint is strongly projecting; and there is no notch for the reception of the fourth joint; the palpus is broad.

6. MICROPISA OVATA Stimpson

PLATE I, FIG. 3, 3a

Micropisa ovata STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 217 [24], 1857.

In this little crab the carapax is rather depressed, and but little longer than broad. The regions are sufficiently prominent, but generally smooth and rounded; there are, however, three inconspicuous protuberances on the genital and three on each branchial region. Surface pubescent, the more prominent portions often surmounted by a few curled setæ. The antero-lateral margin is swollen, but without teeth, except that immediately behind the post-orbital tooth and a small conical one at the lateral extremity of the branchial region. The chelopoda of the adult male are robust; the meros toothed along the angles; the hand smooth, somewhat compressed, and surmounted above by a ridge. Posterior four pairs of feet pubescent; the meros with a small tooth at the summit and one or two near the base. Length of carapax, 0.4; width, 0.38 inch.

Several specimens were taken in the harbor of Porto Praya, Cape de Verde Islands. They were dredged on a nullipore bottom at the depth of 20 fathoms.

Genus TIARINIA Dana

In addition to the characters given by Dana as defining this well-marked group, the following may be added. The palpus of the external maxillipeds is very broad; but little less than three-fourths as broad as the ischium or second joint; the antero-exterior angle of the meros is consequently much produced. As in many other genera of Maioids, the fingers of the chelopoda are in contact throughout their length in the young, but touch each other only at their tips in the adult; the dactylus bears a strong tooth within near its base. In *Tiarinia* the præorbital spine is more prominent than the tooth of the basal joint of the external antennæ, projecting over and concealing it; in *Pericera*, on the contrary, the antennal tooth is more prominent than the præorbital.

It has been usual to place *Pericera* and its allies near the *Menætheinæ*, along with *Halimus* and *Pugettia*, on the ground of the non-retractility of the eyes. But the eyes should scarcely be called non-retractile, when, as may be seen in any wet specimen, they are really more completely retractile than in any other genus of Maioids, and may be drawn in so far as to be completely hidden. It is true that this is not a folding back, as in *Hyas* and *Inachus*, but a direct

withdrawal into a sheath. *Pericera* is nearly allied to *Pisa;* in fact, *P. bicorna* is placed by some naturalists in one genus and by others in the other. The peculiar character of the orbit, however, seems to warrant the establishment of a new family division for the reception of this genus and *Tiarinia.*

7. TIARINIA CORNIGERA (Latreille)

PLATE III, FIG. 1

Pericera cornigera LATREILLE, Encyc., x, 141.
MILNE EDWARDS, Hist. Nat. des Crust., I, 335.
ADAMS and WHITE, Zoölogy of the Samarang, Crust., 18.
?*Tiarinia cornigera* DANA, U. S. Exploring Expedition, Crust., I, 110, pl. III, f. 5.

Our specimens differ from those described and figured by Dana in having, at the summit of the intestinal region, one very large and two inconspicuous tubercles, instead of three of equal size. They are also much larger, some being nearly two inches in length.

They are found on the reefs at low-water mark, and were collected at the Amakirrima Islands by the officers of the steamer "John Hancock" and by myself at Loo Choo and Ousima.

8. TIARINIA DEPRESSA Stimpson

PLATE III, FIG. 2

Tiarinia depressa STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 217 [24], 1857.

Carapax in shape much like that of *T. cornigera;* proportion of breadth to length, 1 : 1.5; form depressed; upper surface with tubercles less numerous and more flattened than in the *cornigera.* There is a small marginal spine on each side at the branchial region, above which an arc of four depressed warts extends around the side; the first (posterior) one largest, and placed a little behind the level of the trituberculated cardiac protuberance; the fourth, and smallest, is near the anterior extremity of the branchial region, with a still smaller one before it. A submarginal channel of some depth passes around behind, above the intestinal region. Posteriorly, at the upper or intestinal margin there is a subtriangular median tubercle, with a smaller trilobate one on either side of it; on the lower margin there are four small tubercles. On the stomachal region there are three warts in the median line, the anterior one smallest, and placed some little distance before the others, with a wart on either side of it; behind the posterior one there are two

warts placed close together. The ambulatory feet are depressed, smooth above, their edges not spinulose, but sparsely fringed with stout clavate setæ. Only one specimen of this species was taken—a sterile female—the dimensions of which are: Length, 0.77; breadth, 0.52; length of a foot of second pair, 0.67 inch.

In the characters of the rostrum, orbits, etc., our species much resembles *T. cornigera*. The tooth at the external angle of the basal joint of the external antennæ is, however, less prominent than in that species, and the rostrum curves upward at its slender tip, where the horns are slightly divergent. It is more depressed than *T. tiarata;* the forks of the rostrum are less divergent; the præorbital spine less prominent, and is wanting in the woolly hairs characteristic of that species.

The specimen was taken at the island of Ousima, which forms one of the chain connecting southern Japan with Loo Choo.

9. TIARINIA SPINIGERA **Stimpson**

PLATE III, FIG. 3

Tiarinia spinigera STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 217 [24], 1857.

Carapax somewhat elongated, the greatest breadth excluding spines being considerably less than the postorbital length. Upper surface not very convex except at the well-developed gastric region; cardiac region with three tubercles at the summit, placed as usual in the genus; on either side of this on the branchial regions there are three sharp, erect spines, the outer one being lateral, a little larger than the others, and somewhat inclined outward. There is a single longish clavate seta at the summit of each spine. Upper posterior margin with seven small spines, the middle one largest at the summit of the intestinal region; lower posterior margin also with seven spines, but of much smaller size. The sides of the carapax, including the hepatic regions and the posterior half of the upper surface, are covered with small, sharp tubercles occupying the interspaces between the spines and larger warts, while the gastric region, and parts adjacent on either side, although irregularly protuberant, are nearly smooth. Rostrum sharp and very slender, in length equaling two-thirds the interorbital width; horns contiguous throughout their length. Præorbital tooth prominently salient, very slender and sharp, curved upward; a single closed fissure separates it from the somewhat prominent postorbital tooth. The basal article of the external antennæ is broader than long; its antero-exterior

tooth lies close beneath the præorbital tooth, and helps to form the deep tubular orbit, which encloses the eye as in a sheath. The edges of the rostrum and of the external antennæ are, as usual, ciliated; and there are some few crispate setæ on the prominent parts of the carapax anteriorly and at the sides.

In the feet of the anterior pair the carpus and meros are sparingly spinulose above. The ambulatory feet are almost smooth; those of the first pair in the female are scarcely as long as the carapax. The abdomen in the female is tomentose.

Two specimens only of this species were found, both females. The dimensions of the largest are: Length of the carapax, 0.79; breadth, including spines, 0.57 inch.

This species occurred at the islands of Ousima and Tanegasima, of the southern Japanese chain.

10. MICIPPA HAANII Stimpson[1]

Micippa thalia DE HAAN, Fauna Japonica, Crust., 98, pl. XXIII, fig. 3.
Micippa Haanii STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 217 [24], 1857.

The Japanese specimens of this species are said by De Haan to differ from the original specimens of *Cancer thalia,* described by Herbst, in wanting the two spines on the posterior margin of the carapax, and in having a spine on the meros of the ambulatory feet, near its superior extremity. On all of our specimens from the Chinese Sea the characters are the same as those found in De Haan's figure and description, while none present the above-mentioned characters of *C. thalia.* Nor do they agree with the description of Herbst's specimen given by Gerstæcker in the Archiv für Naturgeschichte, vol. XXII, p. 109. Under these circumstances we have been led to consider the species distinct and to propose a new name for De Haan's crustacean.

M. thalia Krauss, which inhabits the coast of South Africa, seems also distinct from the Herbstian species.

11. MICIPPA SPINOSA Stimpson

PLATE I, FIG. 2

Micippa spinosa STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 218 [24], 1857.

Body depressed; proportions of the carapax, breadth to length, as 1 to 1.3; upper surface uneven, crowdedly tuberculated and setose. Spines of the back few in number, but long and slender, with blunt

[1] *Micippa thalia* (Herbst).

extremities. There are three spines on the median line, two of which are on the gastric region, and one, the largest of all, on the cardiac. A large spine on each side on the branchial region, between which and the postorbital tooth, on the lateral margin, there are nine spines, irregular in size and distance. Posterior margin spinulose, three or four spines near the middle being larger than the others. Rostrum inclined at an angle of 45°, and bent at its extremity into the vertical plane; it is dilated at the extremity, the corners being broadly rounded and minutely crenulated; at the middle there are two diverging teeth. Ocular peduncles rather short, in length little more than twice their diameter. Orbit with two fissures above, the inner one closed, the outer open, separating the postorbital tooth. The pterygostomian regions are full convex, tuberculated, and not setose. The third joint of the outer maxillipeds is greatly expanded at its antero-exterior angle; the second joint is marked with a longitudinal furrow near its outer margin. The basal joint of the outer antennæ is very broad; its anterior tooth short, with nearly smooth margin; second joint oblong, compressed, with the margin ciliated with long hairs. Chelopoda equaling the carapax in length, smooth and glossy, fawn-colored, with white bases; carpus and hand minutely and obsoletely granulated; fingers with black tips. Ambulatory feet compressed, thickly hairy; the meros with a small terminal spine above. Color of the body pale reddish, rendered indistinct by an accumulation of sordes retained by the setæ. Dimensions: Length of the carapax, 0.75; greatest breadth, 0.59; distance between tips of postorbital teeth, 0.45; length of first pair of ambulatory feet, 0.86 inch.

Specimens of this species were dredged on a muddy bottom in six fathoms, in the harbor of Sidney, or Port Jackson, Australia.

12. MICIPPA HIRTIPES[1] Dana

Micippa hirtipes DANA, U. S. Exploring Expedition, Crust., I, 90, pl. I, fig. 4.

The following description is drawn up from specimens preserved in spirits; it may be useful, as Dana's specimens were dried. The body is moderately depressed; carapax minutely and somewhat unequally tuberculated above, without spines, except a small one at the branchial region on each side, and a marginal one in front of this; these are continuous with the series of teeth on the antero-lateral margin. The posterior margin is denticulated with granular tuber-

[1] *Micippa philyra* (Herbst).

cles somewhat larger than those of the surface, the median two being larger and dentiform. The antero-lateral margin curves upward a little and shows nine minute teeth, two of which, in the depression between the hepatic and branchial regions, are much larger than the others. The superior margin of the orbit is two-fissured. The eye-peduncles are exposed throughout their length, and fully reach the tip of the tooth formed by the external angle of the orbit. Rostrum broader than long; its upper surface with two convex ridges; extremity broader than the base, and four-toothed, the middle teeth being short, triangular, and blunt, the lateral ones sharp and curved upward. The movable part of the antennæ is at the base of the rostrum, separated from the orbit only by the narrow, projecting, terminal edge of basal joint, which, seen from above, forms a slender tooth. Below, the surface of this basal joint is smooth.

The upper surface of the body is hairy; the ambulatory feet densely so; hectognathopoda also hairy. First pair of ambulatory feet long. Dactyli much curved. The dimensions of a female specimen are as follows: Length of the carapax, 0.59; greatest breadth, 0.48 inch; proportion, 1 : 1.23; length of first pair of ambulatory feet, 0.64 inch.

Our specimens differ somewhat from Dana's figure in the greater prominence of the tooth of the basal joint of the antennæ, which projects so as to appear conspicuously above. The species is, however, undoubtedly the same. It approaches *M. philyra* in character, but is more hairy, the margins with smaller teeth, the teeth of the rostrum shorter and the outer ones recurved, and the movable part of the antenna not widely separated from the orbit. It has also some resemblance to *M. platipes* Rüppell, but has not the sharp terminal rostral teeth of that species.

Our specimens were taken at the islands of Loo Choo and Ousima. Those of the U. S. Exploring Expedition are from Tongatabu.

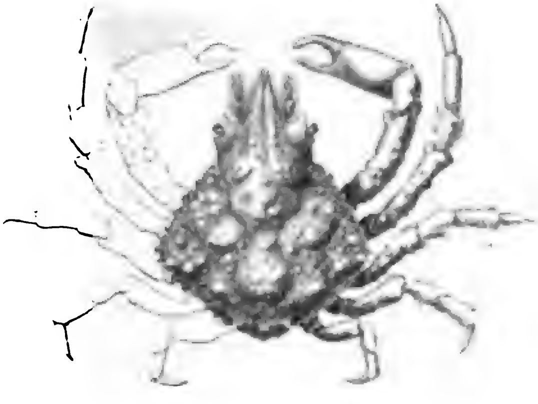
Genus NAXIA Milne Edwards

13. NAXIA DICANTHA[1] De Haan

Naxia dicantha DE HAAN, Fauna Japonica, Crustacea, p. 96, pl. XXIV, fig. 1.

In living specimens of this species the body is covered with sordes; when cleaned it is found to be of a yellowish-brown color above and below, the feet annulated with pale purplish-brown. There is a great diversity in the size of the hand and the shape of the fingers shown

[1] *Halimus diacanthus* (De Haan).



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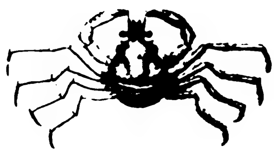

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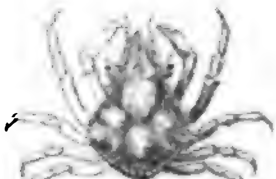

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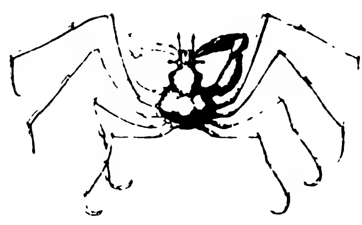

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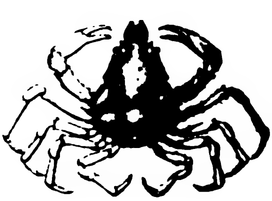

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8

CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

between large males and those of ordinary or small size, as mentioned by De Haan.

The diversity in the shape of the rostrum in *Naxia serpulifera* and *N. dicantha* does not seem of sufficient importance to warrant a generic separation. The deep orbits, with peculiar fissures widening at the bottom, are characteristic of both, although in *N. dicantha* the inferior fissure is much broader than in the other species. There is, however, in the Japanese species a notch in the margin of the meros of the hectognathopod at the insertion of the carpus, while in *N. serpulifera,* judging from Guérin's figure, that margin is entire.

Naxia dicantha was taken by the expedition at the following localities: Hongkong harbor, abundant on shelly bottoms in 10 fathoms; Northern China Sea, in 20 fathoms; Kagoshima Bay, Japan, in 20 fathoms, shelly bottom.

Genus SCYRA Dana

14. SCYRA COMPRESSIPES Stimpson

PLATE III, FIG. 4

Scyra compressipes STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 218 [25], 1857.

Carapax irregularly ovate; proportion of breadth to length, 1 :1.27 (rostrum and lateral spines included). It is rather depressed posteriorly, well contracted between the hepatic and branchial regions. Gastric region ample, rounded above, and nearly smooth, with the exception of two or three minute tubercles along the median line and one on either side posteriorly. There is a sharp tubercle on each side at the hepatic region, and a short, sharp spine, extending horizontally and somewhat curving forward at the summit of each branchial region. Cardiac and intestinal regions rather small and only moderately elevated. Posterior margin with a slightly prominent tubercle at the middle. Rostrum scarcely as long as broad, laminiform, scarcely contracted at base; horns shorter and less acuminate than in *S. acutifrons.* Præorbital tooth prominent and acute, but rather short. Parts about the head below much as in *S. acutifrons.* The tooth forming the external angle of the orbit is deeply concave below, leaving the orbit at that point widely interrupted. Margin of the pterygostomian region with three small, obtuse, lobelike teeth; a deep sinus separates this margin from that of the side of the carapax. Feet all much compressed. Meros of chelopoda four-sided or prismatic, obtusely tuberculated along the angles; superior edge with blunt teeth near the base, and one prominent

sharp tooth near the extremity, being one of three large teeth surrounding the insertion of the carpus. Superior and inferior edges of ambulatory feet somewhat setose; the penultimate joints of these feet, however, are smooth and slender. In this and the other known species of the genus the setæ are stout and clavate in form.

The dimensions of a sterile female are: Length of carapax, 0.65; greatest breadth, 0.51 inch.

This species was dredged in the harbor of Hakodadi, Island of Jesso, Japan, on a bottom of weedy sand, at the depth of 6 fathoms.

Only one other species of the genus is known, *S. acutifrons* Dana, which inhabits the opposite coast of the North Pacific.

Genus DIONE De Haan

15. DIONE AFFINIS[1] De Haan

Dione affinis De Haan, Fauna Japonica, Crustacea, 94, pl. xxii, fig. 4.

The only specimen taken is young, the dimensions of the carapax being: Length, 0.57; greatest breadth, 0.41; breadth between præorbital spines, 0.35 inch. Proportion of this interorbital breadth to the length, 1:1.63. This proportion in De Haan's figure is 1:1.93. Our specimen differs from those described by De Haan in its more depressed form, its narrower and smoother carapax and broader front. There is no tooth within at the base of the movable finger and none on the outer base of the hand. The horns of the rostrum are longer than in the adult *D. affinis*, and the abdomen of the male is not dilated near the base.

Having no opportunities of comparing our specimen with the young of the species to which it is here referred, we do not venture to consider it distinct.

It was taken in a harbor on the northwest coast of the Island of Ousima.

Genus MITHRAX Leach

16. MITHRAX SUBORBICULARIS[2] Stimpson

Plate IV, Fig. 1

Mithrax suborbicularis Stimpson, Proc. Acad. Nat. Sci. Phila., ix, p. 218 [25], 1857.

This species belongs to the division "Mithrax transversaux" of Milne Edwards. The following description is taken from a sterile female, the only specimen found. Carapax rounded, not narrowed

[1] *Schizophrys aspera* (Milne Edwards).

[2] *Cyclax* (*Cyclomaia*) *suborbicularis* (Stimpson).

anteriorly; length and breadth equal; margins dentated with teeth of moderate size. Gastric region broad and convex. Upper surface with about thirty small, nearly equidistant prominent warts; the interspaces granulated. Rostrum formed of two small, sharp, triangular, diverging horns, outside of which, on either side, project three slender spines belonging to the anterior margin of the basal joint of the antennæ. Eyes large. Superior margin of orbit with two deep fissures and three teeth, the middle one of which is short, truncate, with a trifid clove-like apex. The tooth at the external angle of the orbit is rather long and sharp, curving forward; immediately behind this there are two teeth on the antero-lateral margin just in front of the hepatic constriction. Behind this constriction on the lateral margin of the carapax there are six teeth, the posterior ones very small, and placed rather above than *on* the margin. At the posterior extremity of the shell there are two small blunt submarginal teeth. Outer pterygostomian regions with granulated surface, upon which arise a few tubercles. Hectognathopoda and the adjoining triangular surface smooth and ungranulated. Fossæ of the inner antennæ excavated in the inferior side of the horns of the rostrum. Chelopoda small, slender, smooth, and glossy. Ambulatory feet hairy above; three of the joints spinulose; below smooth. Those of the posterior pair nearly smooth above.

The color in the preserved specimen is white, tinged with reddish-brown. Dimensions: Length of carapax, 0.8; greatest breadth, the same; breadth between tips of the larger spines of the antennæ, 0.4; between tips of the spines at outer angle of orbit, 0.57 inch.

It was taken at Selio Island, Gaspar Straits, by Mr. L. M. Squires, of the steamer "John Hancock."

Genus CAMPOSCIA Latreille

17. CAMPOSCIA RETUSA Latreille

Camposcia retusa LATREILLE, Règne Anim., 2d ed., IV, 60. GUÉRIN, Icon., pl. IX, fig. 1. MILNE EDWARDS, Hist. Nat. des Crust., I, 283, pl. XV, figs. 15, 16; Cuv. R. Anim. Crust., pl. XXXII, fig. 1. ADAMS and WHITE, Voy. Samarang, Crust., p. 6.

The specimen is a fully developed female. It is covered with a thick growth of *ulvæ,* indicating the sluggish habits of the species. The abdomen does not appear to have been described; it is seven-articulate, depressed, suborbicular, but longer than broad, with a transverse convexity at the middle of each joint, forming a low median ridge, less conspicuous on the first and last joints. The terminal knobs of the rostrum are only the extremities of two slight,

longitudinal, minutely nodulose ridges on its upper surface; between them there is a small tooth or point projecting downward, formed by the emargination. In our specimen the postorbital tooth seems less strong than in Milne Edwards's figure (Hist. Nat. des Crust., pl. xv, figs. 15, 16), and there are no warts on the gastric region.

Dredged from a weedy and sandy bottom in 2 fathoms, in a harbor of Ousima.

Genus ACHÆUS Leach

18. ACHÆUS JAPONICUS De Haan

Achæus japonicus De Haan, Fauna Japonica, Crust., p. 99, pl. xxix, fig. 3. Adams and White, Voy. Samarang, Crust., p. 5.

In our specimens the spines of the ocular peduncles are obsolete, and the falciform dactyli of the posterior feet are much curved, forming nearly a semicircle.

Taken in the harbor of Hongkong, China.

19. ACHÆUS LACERTOSUS Stimpson

Plate III, Fig. 7

Acheus lacertosus Stimpson, Proc. Acad. Nat. Sci. Phila., ix, p. 218 [25], 1857.

The following description is taken from an adult male: Carapax, triangular; proportion of breadth to length, 1:1.8; regions sufficiently prominent; surface smooth and slightly pubescent, without spines. A small, flattened, wing-like projection at the hepatic region. Rostrum as long as broad, with bilobate extremity; its upper surface two longitudinal convexities corresponding to the deeply excavated fossæ below. External antennæ hair-like, longer than the body. Peduncles of the eyes smooth. Chelopoda very large, resembling considerably those of *Myctiris;* they are somewhat longer than the body; meros much swollen and larger than the hand, with two granulated ridges below and one above, the latter bearing also two small spines; carpus with a small tubercle or spine at the summit near its articulation with the meros; there are a few rather long hairs at the inner angles of the carpus and meros; hand somewhat curved, with the fingers small, slender, compressed, and curved, touching each other throughout the length of their denticulated inner edges. The chelopoda are separated below at their bases by a wide depressed space. Ambulatory feet exceedingly slender; those of the first pair longest and nearly three times as long as the body. Feet of the last two pairs with much-curved falciform dactyli; the penult

article subcylindrical and slender. Abdomen consisting of six segments, all of which are exposed by the shortness of the carapax posteriorly; extremity broad. Dimensions of carapax: Length, 0.385; breadth, 0.325 inch.

This species was dredged on a muddy bottom in 6 fathoms, in the harbor of Port Jackson, Australia.

Genus ACHÆOPSIS Stimpson

Achæopsis STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 219 [25], 1857.

In this genus the general appearance resembles that of *Achæus,* and the terminal joints of the feet of the posterior three pairs are falciform. As in *Eurypodius,* the eyes are retractile, but without orbits, and the external antennæ are not concealed beneath the rostrum. The antennulary fossæ are very large, and excavated in the under side of the horns of the small bifid rostrum. The basal joint of the external antennæ is narrow and placed almost in a vertical plane, as in *Leptopodia.*

20. ACHÆOPSIS SPINULOSUS Stimpson

PLATE III, FIG. 5, 5*a*

Achæopsis spinulosus STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 219 [25], 1857.

Description of a developed female. The carapax is rather thick and convex above, the sides rounded; the regions not strongly defined, and rising but little beyond the general surface. The surface is minutely and inconspicuously pubescent. The spines on the upper surface of the carapax are all small, about equal in size, and very sharp and slender; there are three on the gastric region, one placed posteriorly in the median line, the other two on the sides between the median and the postocular spines. The somewhat protuberant summit of the cardiac region is unprovided with a spine, but there are two on each branchial region. Four minute spines on the hepatic region and a few placed along the inferior lateral margin of the carapax. The rostrum is rather longer than it is broad at its base, and divided for more than half its length, with the horns acute. The small, sharp præocular spine points obliquely upward and forward. The ocular peduncles in length equal about half the interorbital space; they bear a slight tooth inferiorly in front and a minute spine at the summit of the eye. The narrow basal joint of the external antennæ curves upward and slightly outward at the base of

the rostrum, and is denticulated along the edge. The surface of the external maxillipeds is ornamented with subspiniform and setose granules, except at the longitudinal sulcus of the ischium-joint; the exposed surface of the palpus is also granulated. Chelopoda rather large, even in the female, and nearly one-half longer than the carapax; they are everywhere spinulose above, except on the fingers of the hand, which are smooth, curved, with their inner margins contiguous, inconspicuously denticulated. Ambulatory feet hairy, somewhat irregularly and minutely spinulose above; terminal joints in the posterior three pairs short, not greatly curved. Dimensions: Length of carapax, 0.36; breadth, 0.28; length of first pair of ambulatory feet, 0.67 inch.

Dredged in Simons Bay, Cape of Good Hope, in 10 fathoms.

Genus STENORYNCHUS Lamarck

21. STENORYNCHUS PHALANGIUM [1] (Pennant) Milne-Edwards

Cancer phalangium PENNANT.
Cancer rostratus LINNÆUS, Fauna Suecica, No. 2027.
Macropodia phalangium LEACH, Zoöl. Misc., pl. II.
Stenorynchus phalangium MILNE EDWARDS, Hist. Nat. des Crust., I, 279; Cuv. R. Anim. Crust., pl. XXXV, fig. 3.
Stenorynchus rostatus BELL, Brit. Crust., p. 2. LILJEBORG, Öfvers. af Kongl. Vet.-Ak. Förhand., 1855, p. 118.

This species was dredged in 15 fathoms, sandy bottom, off the town of Funchal, Madeira.

22. STENORYNCHUS FALCIFER [2] Stimpson

PLATE III, FIG. 8

Stenorynchus falcifer STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 219 [26], 1857.

Body rather slender, but high and rounded; carapax minutely pubescent; proportion of breadth to length, 1 : 1.79. There are two long erect spines on the upper surface, one at the summit of the gastric, the other on the cardiac region; there are also a few small spines or sharp tubercles on the sides of the body. Rostrum constituting more than one-fourth the length of the carapax, and very slender, composed of two acicular horns, contiguous throughout their length, and so closely pressed against each other that one is usually crowded up over the other, as if twisted. External antennæ

[1] *Macropodia rostrata* (Linnæus).
[2] *Macropodia falcifera* (Stimpson).

not concealed beneath the rostrum; basal joint lateral, or in a vertical plane, with a small spine at the inferior face. Antennulary fossæ large and wide. Eyes saliant, with a sharp minute spine at the summit. Chelopoda in the female and young male hairy and somewhat spinous; meros with a long spine at the summit; carpus with two spines; hand much curved, fingers forming half the length of the hand and denticulated within. Ambulatory feet slender, rather smooth, with a few scattered hairs; a strong spine at the summit of the meros in each pair. Dactyli of the posterior two pairs of feet falciform, as in the genus *Achæus*. Color, brick-red. Dimensions of a female: Length of carapax, 0.61; breadth, 0.35; length of rostrum, 0.19; of first pair of ambulatory feet, 1.75 inches.

It has considerable resemblance to *S. phalangium* in many of its characters, but the two large dorsal spines at once distinguish it. The terminal joints of the last two pairs of feet are falciform, a character not to be found in diagnoses of the genus, but we may observe a strong approach to this form in the posterior dactyli of *S. phalangium* and some other species.

Taken among sea weeds, etc., in 12 fathoms, on a sandy bottom, in Simons Bay, Cape of Good Hope.

Genus LEPTOPODIA Leach

23. LEPTOPODIA SAGITTARIA[1] (Fabricius) Leach

Inachus sagittarius FABRICIUS, Suppl., 359.
Leptopodia sagittaria LEACH, Zoöl. Misc., II, pl. LXVII. MILNE EDWARDS, Hist. Nat. des Crust., I, 276.

This species was dredged in 30 fathoms off the south side of Madeira. It is found on the shores of Florida and the West Indies, and is said by Brullé to occur at the Canary Islands.

Genus PERINEA Dana

24. PERINEA TUMIDA Dana

Perinea tumida DANA, U. S. Exploring Expedition, Crust., I, 114, pl. IV, fig. 1.

Our specimens agree well with those of Dana, except that in the male the pincers are much smaller and less gaping, while the size of the carapax is the same; this may, however, result from a difference of age and development.

Taken from branches of Madrepora, found below low-water mark near Hilo, Island of Hawaii.

[1] *Stenorynchus sagittarius* (Fabricius).

Genus PUGETTIA Dana

Having secured specimens of two species of Japanese Maioid crabs, referred by De Haan to the genus *Menæthius*, we find them perfectly similar, in all characters which may be considered generic, to the *Pugettiæ* of the North American coast. The range of the genus, therefore, extends throughout the North Pacific. In addition to the characters given by Dana for the genus, we may mention the following: There is no postorbital spine, other than that forming the anterior angle of the hepatic expansion. The pterygostomian ridge is denticulated. There is a small tuberculiform tooth at the exterior base of the first joint of the antennæ. The chelopoda are very large in the male.

The lyrate form of the carapax, with two angular projections on either side, otherwise without spines, is quite characteristic. The body of the female is more swollen above than that of the male. The species are generally very clean and neat for Maioids, and free from pubescence.

25. PUGETTIA INCISA[1] (De Haan) Stimpson

Menæthius incisus DE HAAN, Fauna Japonica, Crust., p. 98, pl. XXIV, fig. 3. ADAMS and WHITE, Voy. Samarang, Crust., p. 20.

This seems to represent *P. gracilis*. Recent specimens are of a reddish or chestnut color above, white below; pincers brown, tipped with white.

It differs from *P. quadridens* in the less projecting and much less concave hepatic expansions; also in the smaller chelopoda of the male. The fingers of the hand are contiguous almost throughout their length.

It was found on a sandy and weedy bottom, at the depth of 6 fathoms, in the Bay of Hakodadi, Japan.

26. PUGETTIA QUADRIDENS (De Haan) Stimpson

Menæthius quadridens DE HAAN, Fauna Japonica, Crustacea, p. 97, pl. XXIV, fig. 2. ADAMS and WHITE, Voy. Samarang, Crust., p. 20.

Living specimens are of a sea-green color, with the abdomen speckled with white. The species represents *P. Richii* of the Californian coast.

It was found among sea weeds dragged up from stony bottoms, at the depth of 1 and 2 fathoms, on the coast of China, near Hong-

[1] *Pugettia quadridens* (De Haan).

kong; also on fuci at low-water mark in the harbor of Simoda, Japan.

Genus MENÆTHIUS Milne Edwards

27. MENÆTHIUS SUBSERRATUS[1] Adams and White

Menæthius subserratus ADAMS and WHITE, Voy. Samarang, p. 18, pl. IV, figs. 1, 2. DANA, U. S. Expl. Exped., Crust., I, 122, pl. IV, fig. 7.

This species would seem scarcely to differ from *M. monoceros,* judging from Rüppell's figure, which is a fair representation of some of our Chinese specimens. But the members of this genus are greatly variable and a great number of specimens is required for their accurate determination.

It was taken by the expedition at Hongkong, China, and at the Amakirrima Islands.

It is also reported from the Philippine, Fiji, and Samoan Islands.

28. MENÆTHIUS DENTATUS[2] Stimpson

PLATE III, FIG. 6

Menæthius dentatus STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 219 [26], 1857.

This species has much resemblance to *M. subserratus,* but the lateral teeth and the tubercles of the dorsal surface are much more prominent than in any specimens of that species which have come under our notice. The following description is taken from an adult male: Proportion of breadth of carapax to length, 1 : 1.5. Depressions between the regions deep. The cardiac region is very prominent and ample, occupying one-third the width of the carapax. Lateral teeth sharp and subtriangular; the two teeth on the antero-lateral margin prominent, projecting well over the sides of the carapax, and bilobate, with the anterior lobe smallest. The two tubercles on the gastric region are sharply protuberant and covered in front with crispate setæ. The surface is elsewhere clean, with the exception of a slight pubescence on the sides and a dense pilosity on the rostrum. Interorbital space rather narrow, very smooth and flat, with the exception of the bituberculate anterior extremity of the gastric region. Rostrum rather long, curving a little upward toward the extremity. Præorbital teeth very long, pointing forward in a longitudinal direction. Chelopoda large; the hand rather compressed;

[1] *Menæthius monoceros* (Latreille).

[2] *Menæthius monoceros* (Latreille).

fingers short, contiguous at the denticulated exterior third of their length; a broad, blunt tooth at inner base of dactylus. Ambulatory feet rather smooth, glossy; two small setiferous teeth on upper side of meros; sometimes two or three points on the thick carpus. Dimensions: Length of carapax, 0.84; of rostrum, 0.25; of chelopod, 0.96; breadth of carapax, 0.56; interorbital width, 0.2 inch.

Taken at the Amakirrima Isles, near Great Loo Choo, by the officers of the steamer "John Hancock," Captain Stevens.

29. MENÆTHIUS DEPRESSUS[1] Dana

Menæthius depressus DANA, U. S. Expl. Exped., Crust., I, 121, pl. IV, fig. 6.

The specimens taken are all of small size, although somewhat exceeding in dimensions those described by Dana. The color is a uniform light-green above and below. Eyes black.

Taken on sargassum from rocks near low-water mark at Loo Choo.

Genus ACANTHONYX Latreille

30. ACANTHONYX DENTATUS[2] Milne Edwards

Acanthonyx dentatus MILNE EDWARDS, Hist. Nat. des Crust., I, 343. KRAUSS, Sudafrik. Crust., p. 48.

Living specimens are of an olive color. Found on seaweeds from 12 fathoms, sand, in Simons Bay, Cape of Good Hope.

Genus EPIALTUS Milne Edwards

31. EPIALTUS PRODUCTUS Randall

Epialtus productus RANDALL, Jour. Acad. Nat. Sci. Phila., VIII, 110. DANA, U. S. Expl. Exped., Crust., I, 133, pl. VI, fig. 2. STIMPSON, Crust. and Echin. of the Pacific shores of N. America, Bost. Jour. Nat. Hist., VI.

Found near San Francisco, Cal.

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[1] *Menæthius monoceros* (Latreille).
[2] *Dehaanius dentatus* (Milne Edwards).

PARTHENOPIDÆ

Genus EURYNOME Leach

32. EURYNOME LONGIMANA Stimpson

PLATE IV, FIG. 2

Eurynome longimana STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 220 [26], 1857.

Carapax with the regions distinct, but not deeply separated; proportion of breadth to length, 1 : 1.38. Upper surface rugose, the rugosities consisting of rounded flattened warts somewhat irregular in size, and sometimes confluent. A large triangular tooth behind the orbit, at the hepatic region; five teeth on the branchial region, four of which are marginal or submarginal, and one erect at the center of the region. Two small spines on the gastric region. Cardiac region rather prominent, oblong. Posterior margin with a slight protuberance on each side. Rostrum deeply bifid; horns long and sharp, somewhat divergent. Orbits and antennæ much as in *E. aspera,* except that the superior orbital fissure is not open. Hectognathopoda roughly granulated. Chelopoda of male nearly twice as long as the carapax, granulated and somewhat spinous; hand rather slender, with three or four stout spines toward extremity on superior inner margin. Pincers deflexed. Ambulatory feet bicarinate above, the carinæ most distinct on the meros, where they are each 3 to 4 toothed.

In the female the carapax is pubescent and more convex than in the male; the chelopoda are very short, and the hand scarce twice as long as broad.

Colors: Carapax above dull red; feet whitish or variegated with pale red; eyes small, black.

Dimensions: Male, length of carapax, 0.47; breadth, 0.34; length of rostrum, 0.12; of chelopod, 0.8 inch; female, length of carapax, 0.39; of chelopod, 0.3.

Dredged in 10 fathoms, on a rocky bottom, among *Gorgoniæ,* etc., in False Bay, Cape of Good Hope.

Genus LAMBRUS Leach

33. LAMBRUS RUGOSUS[1] Stimpson

PLATE IV, FIG. 3

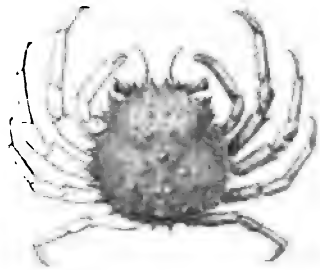
Lambrus rugosus STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 220 [27], 1857.

Carapax nearly as long as broad, with very irregular and partly tuberculated surface; front with a deep, smooth, longitudinal concavity. An irregularly tuberculated ridge extends on either side obliquely across the branchial region to the posterior of the lateral teeth, enclosing a rather broad and depressed area, in which the granulated cardiac region forms a slight eminence. Beneath the ridge on the branchial region there are three principal tubercles. Lateral margin with about ten teeth, the first at the hepatic edge, rather prominent; the next eight very small, but sharp and deeply cleft, minutely denticulated, and about equal in size; the posterior tooth elevated and separated from the rest by a short space, large and conical, with a denticle on each side at its base. Posterior margin with four or five very small, distant tubercles only. Rostrum oblique, longer than broad at base, tapering, but with rounded extremity; a minute marginal tubercle at its base on each side. Chelopoda of moderate length, rugose, and tuberculated above; meros with two sharp teeth on the front edge. Hand with the upper surface sloping inwards and broadest at the middle, the keels not being parallel; three large tubercular teeth on outer keel, the third being at the insertion of the dactylus; six small teeth on inner keel, the middle one sharply prominent, the others less conspicuous. Inferior surface of chelopoda nearly covered with tubercles, which are smooth, rounded, equal, and but little elevated; of these there are four rows on the infero-exterior surface of the hand. Five or six small teeth on the triangular space at the superior base of the dactylus. Ambulatory feet nearly smooth; a few small spines on the superior edge of the meros.

In the young female the gastric and branchial regions are more deeply separated; the rostrum is shorter and blunter and the tubercles less numerous on the inferior surface of the chelopoda.

The dimensions of a male are as follows: Length of carapax, 0.34; greatest breadth (at the small ninth or penultimate lateral tooth), 0.35; length of rostrum, 0.07; of chelopod, 0.5 inch.

[1] *Parthenope rugosa* (Stimpson).



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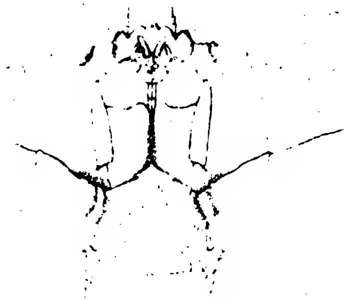

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CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

Dredged off the harbor of Porto Praya, Cape de Verde Islands, in 20 fathoms, among nullipores.

34. LAMBRUS LACINIATUS[1] De Haan

Lambrus laciniatus DE HAAN, Fauna Japonica, Crust., p. 91, pl. XXII, figs. 2, 3. ADAMS and WHITE, Voy. Samarang, Crust., p. 29.

Recent specimens are of a reddish or yellowish-brown color above, paler and sometimes whitish below. Hands tipped with a dark mahogany color.

Young specimens, the carapax of which is not over two-thirds of an inch in length, are much smoother than the adults, with few tubercles on the surface of the body and none on the flat faces of the chelopoda. The teeth on the margins of the carapax and hands are small, little projecting, and scarcely denticulated.

This species is very common in the seas adjacent to the shores of Southern China, particularly about Hongkong. It inhabits muddy bottoms in from 5 to 20 fathoms. One specimen was taken in 25 fathoms, shelly bottom, near the middle of the Northern China Sea.

35. LAMBRUS TUBERCULOSUS[2] Stimpson

PLATE IV, FIG. 4

Lambrus tuberculosus STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 220 [27], 1857.

In form, length of arms, and general appearance this species is similar to *L. validus*. Proportion of length to breadth of carapax, 1 : 1.21. Branchial regions separated from the median ones by profound depressions. Surface above everywhere covered with small flattened tubercles of nearly equal size. These tubercles are generally smooth on their flattened upper surfaces, and are each surrounded by a ring or crown of granules, thus resembling the *paxilli* of some kinds of starfishes. Two or three along the median line are larger and more prominent than the others. Lateral margin of the carapax with ten serrated and granulated teeth, the first one a slight lobe at the hepatic region; the posterior two very much larger than the others, sharply projecting, and ramose on all sides with denticulations. Beneath and within the posterior one there is a much smaller one of similar character. Posterior margin with three granulated knobs, the middle one smallest and trilobate. Front deeply

[1] *Parthenope laciniata* (de Haan).

[2] *Parthenope tuberculosa* (Stimpson).

concave above; rostrum subtriangular and pointed, with its sides a little concave. Surface of hectognathopoda and of the pterygostomian regions roughly granulated. Chelopoda with strong, acute, granulated teeth along the keels; teeth varying in size, eleven on the outer and ten on the inner keel of the hand; upper surface of meros and hand also with two intermediate rows of granulated tubercles, either subspiniform or rounded. Infero-interior surface of chelopoda also tuberculated; the tubercles small, flattened, arranged in three or four longitudinal rows. Ambulatory feet very small and weak, compressed, and spinous above; spines in three rows, one at each edge and one along the middle of the upper surface; dactyli smooth. Dimensions of the single specimen found, a male: Length of carapax, 0.66; breadth between tips of lateral teeth, 0.8; breadth excluding these teeth, 0.67; between elbows of chelopoda, 1.8; length of hand, 0.8 inch.

The species is found living in company with *L. laciniatus,* to which it has considerable resemblance, but the character of the very numerous tubercles on the surface of the carapax and arms will serve to distinguish it.

Taken in 15 fathoms, on a bottom of shelly mud, near Hongkong, China.

36. CRYPTOPODIA CONTRACTA Stimpson

PLATE IV, FIG. 6, 6*a*

Cryptopodia contracta STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 220 [27], 1857.

In this species the carapax is smaller, with less lateral expansion and greater convexity than in any yet described. These and other points in its general appearance indicate an approach to *Lambrus.*

Carapax triangular; proportion of length to breadth, 1 : 1.45. Lateral angles truncated. Front concave along the median line; rostrum of the usual form, and nearly horizontal, but blunt and smoothly rounded at the extremity. The antero-lateral margin is concave behind the orbit, there being a slight contraction at the hepatic region; behind this point the margin is waved to a minute tooth at the anterior end of the lateral truncation, and crenulated, the crenulations about nine in number. The posterior margin is straight and obsoletely crenulated.

The upper surface of the carapax is strongly convex across the branchial regions, the posterior slope being nearly perpendicular and covered on the sides with depressed tubercles. Cardiac region convex, but not rising so high as the branchial region on either side.

Around and particularly in front of the cardiac region there is a depression. At the summit of the small gastric region four obtuse ridges meet in a slight transverse ridge, the two anterior, less conspicuous ones being those of the front; the two posterior ones more strongly marked, enclosing the median depression, and reaching to the branchial eminences. Chelopoda rather long; hand subprismatic, robust, with the superior crest six-toothed, the outer keel granulated; under surface somewhat convex and regularly tuberculated with stout, flattened tubercles showing a tendency to arrangement in four or five longitudinal rows, those of the outer row smallest. Lower surface of meros also tuberculated. Ambulatory feet compressed, ischium and meros with two spinous keels beneath. Abdomen and sternum with an eroded or somewhat vermiculated surface, but neither granulated nor spinulose.

Color of the animal a dusky orange or light brownish; fingers pale brown. Dimensions of a male: Length of carapax, 0.38; breadth, 0.55; between the elbows, 0.83; length of one of the chelopoda, 0.65 inch.

Taken on a bottom of shelly sand, in 25 fathoms, in the China Sea, about the middle, at latitude 23°.

Genus CRYPTOPODIA Milne Edwards

37. CRYPTOPODIA FORNICATA (Fabricius) Milne Edwards

Parthenope fornicata FABRICIUS.

Cryptopodia fornicata MILNE EDWARDS, Hist. Nat. des Crust., I, 362. DE HAAN, Fauna Japonica, Crust., p. 90, pl. XX, fig. 2. DANA, U. S. Exploring Expedition, Crust., I, 140. GIBBES, Proc. Elliott Soc., I, 32 (wood-cut). Vix ADAMS and WHITE, Voy. Samarang, Crust., pl. VI, fig. 4.

The living animal is cream-colored, with small purplish-brown dots above. Below white, with a pale rose tint. Red punctæ on the inferior surface of the posterior projecting shield of the carapax.

The specimen figured by Adams and White belongs most probably to a distinct species, for the pustulation of the surface in Parthenopoid crabs rather increases than diminishes with age, and the short, thick chelopoda represented are quite different from those of the young specimens taken by us.

Cryptopodia fornicata occurred not unfrequently in the harbor of Hongkong, on shelly bottoms, at the depth of about 10 fathoms.

Genus ÆTHRA Leach

The large basal joint (basiocerite) of the external antennæ in this genus is not soldered to the adjacent parts, but is movable as in *Ceratocarcinus.* This adds another character to those mentioned by De Haan as approximating it to the Parthenopidæ. The two genera are also similar in their short and broad epistome, and the ridges of the palate. Future researches may indicate that they, with one or two other genera, form a group distinct from both *Parthenopidæ* and *Cancridæ.*

38. ÆTHRA SCRUPOSA (Linnæus) Milne Edwards

Cancer scruposus LINNÆUS.
Æthra depressa LAMARCK, An. sans vert., v, 265.
Æthra scruposa MILNE EDWARDS, Hist. Nat. des Crust., I, 371; Cuv. R. A., pl. XXXVIII, fig. 2. GUÉRIN, Icon., pl. XII, fig. 3. DE HAAN, loc. cit., p. 81.

Taken among the islands of Gaspar Straits by Mr. L. M. Squires, of the "John Hancock."

Genus CERATOCARCINUS Adams and White

Dana was the first to give the essential characters of this genus, and to point out the remarkable fact that the basal joint of the antennæ is not soldered to the adjacent parts, as in other genera of Parthenopidæ, and, in fact, almost all Brachyura. This observation we are enabled to confirm from examination of full-grown specimens. The joint is flattened, and, fitting closely in the cavity which receives it, does not interrupt the general surface; so that it is only by the application of force that its mobility is discovered. The "coxocerite" containing the organ of hearing is very small and placed close below the basal joint. The eyes are retractile.

Harrovia of Adams and White agrees in all essential characters with *Ceratocarcinus.* In the orbits, antennæ, gnathopoda, and in general appearance they are nearly the same. In their diagnosis of *Harrovia* the authors do not even mention the characters which are of most importance in a generic point of view, their description being confined to details of shape, granulation of surface, dentition of margin, etc. Why they should place the crab among the *Leucosidæ* it would be difficult to decide.

39. CERATOCARCINUS ALBOLINEATUS[1] (Adams and White) Stimpson

Harrovia albolineata ADAMS and WHITE, Voy. Samarang, Crust., p. 55, pl. XII, fig. 5.
Ceratocarcinus albolineatus STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 221 [27], 1857.

Carapax hexagonal in shape, the frontal side being only half the length of the antero-lateral and the posterior side about equal in length to the postero-lateral. Front very slightly convex, emarginate at the middle, the emargination being at the termination of a longitudinal groove or impressed line on the surface of the carapax. On either side of the front a sinus or fissure separates it from the sharp subtriangular præorbital tooth, which projects but very slightly, if at all, beyond the frontal margin. The eyes are retractile, although short and not very mobile. Orbit with two closed fissures above and two notches below. Antero-lateral margin four-toothed (including the angle of the orbit, which is prominent); the posterior or extreme lateral tooth is strongly projecting. The postero-lateral and posterior margins are smooth. Dorsum somewhat convex, nearly smooth, the regions scarcely defined. A small setose eminence on each side of the gastric region, and one on each branchial region just within the lateral tooth. These are not connected by transverse lines in my specimens, although such lines are mentioned by Adams and White. Surface minutely tomentose and granulated; the granulation sharpest and most distinct on the antero-lateral teeth. Chelopoda stout, more than twice as long as the carapax, irregularly granulated; meros with two or three short spines on each side above near the base; carpus with a single small tubercle or spine at the middle of the inner margin; hands smooth, enlarged toward the fingers, which are one-third the length of the hand, and are deflexed as in *Eurynome*. Ambulatory feet minutely and smoothly tomentose, without spines excepting a small blunt one at the summit of the meros.

Colors: Carapax and ambulatory feet pale reddish; pubescence dusky brownish; hands red.

Dimensions of a male: Length of carapax, 0.35; breadth, 0.44; length of a chelopod, 0.96 inch.

Dredged in the harbor of Hongkong, China.

[1] *Harrovia albolineata* Adams and White.

ONCINOPIDÆ

Genus ONCINOPUS De Haan

40. ONCINOPUS SUBPELLUCIDUS[1] Stimpson

Oncinopus subpellucidus STIMPSON, Proc. Acad. Nat. Sci. Phila., IX, p. 221 [28], 1857.

This species is of a soft structure and somewhat translucent in life, the shell being very thin. Surface everywhere pubescent. Color yellowish-brown.

It is very closely allied to *O. aranea* De Haan, but seems to differ in the more slender penultimate joints of the first and second pairs of ambulatory feet; the hair on the feet generally is much longer; the rostrum is more deeply emarginated, and the carapax is more expanded at the hepatic regions behind the eyes. From *O. neptunus* Adams and White it differs in the more slender terminal and penultimate joints of the ambulatory feet.

The dimensions of a male are: Length of carapax, 0.48; breadth posteriorly, 0.36; length of ambulatory foot of first pair, 1.45 inches.

Found on soft sponges dredged from a muddy bottom, in 6 fathoms, in Port Jackson, Australia.

CANCROIDEA

CANCRIDÆ

Genus CANCER (Linnæus) Leach

The reasons given by Bell[2] for following Leach in applying the Linnæan name for all crabs to the group called *Platycarcinus* by Milne Edwards are good, and the name is thus used by most recent carcinologists.

The geographical range of the genus is in the cold temperate zone, and not the "hotter parts of America," as stated by Bell. The species are mostly American, two being found on the northeastern coast of the United States, four on that of Oregon and California, and three on that of Chili. Of the two other known species, one inhabits the shores of Great Britain, the other those of New Zealand.

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[1] *Oncinopus aranea* (De Haan).

[2] Trans. Zoöl. Soc., I, 332.

41. CANCER ANTENNARIUS Stimpson

Cancer antennarius STIMPSON, Proc. Cal. Acad. Nat. Sci., I, 88; Jour. Bost. Soc. Nat. Hist., VI, p. 462 [22], pl. XVIII, 1857.

Carapax convex; proportion of length to breadth in male, 1 : 1.52; in female, 1 : 1.45; greatest breadth at the penultimate antero-lateral tooth. Surface much undulated, very smooth in appearance, but minutely granulated, the granulation being almost obsolete about the middle, but sufficiently well marked toward and at the margin. Antero-lateral margin convex and well rounded, with nine teeth, the first one forming the angle of the orbit; teeth deeply separated, their edges denticulated, their apices curving forward and very sharp, almost uncinate. Postero-lateral margin with a deep emargination near the extremity, forming a sharp tooth, and another, rather slight, a short distance within the first. These emarginations are much deeper in the young than in the adult. Front sufficiently broad, but not projecting beyond the exterior angle of the orbit; interantennary portion with three well-separated teeth, the middle one being smaller and rather below the lateral ones; præorbital tooth rather prominent. External antennæ very large and hairy, in length equaling two-fifths that of the carapax; apex of basal joint projecting considerably beyond the præorbital tooth. Meros of hectognathopoda subquadrate, a little longer than broad; anterior margin nearly transverse, ciliated with long hairs; angles rounded; notch for insertion of carpal joint deep, abrupt below, continuous with the margin above. The slight ridge on the palate near to and parallel with its inner margin is more sharply prominent in this than in other species. Chelopoda large, particularly in the male; carpus and hand rather short and thick, in the adult smoothly rounded above and microscopically granulated; in the young ornamented with small spiniform tubercles; costæ on the hand well marked and granulated in the young, but almost obsolete in the adult. Fingers in the female sulcated. Ambulatory feet hairy; meros overreaching the margin of the carapax; dactylus with thick brushes of short hair along the angles. Margins of abdomen and other parts on the inferior surface generally, very hairy. Terminal joint of abdomen in the male slender, with somewhat concave sides and bluntly pointed extremity.

Color above dark purplish-brown; below yellowish-white, spotted with red; fingers black. Dimensions of carapax in a male: Length, 2.43; breadth, 3.70; in a female, length, 2.13; breadth, 3.08 inches.

This species is not uncommon on the coast of California, inhabiting rocky bottoms in the laminarian zone.

42. CANCER GRACILIS Dana

Cancer gracilis DANA, U. S. Exploring Expedition, Crust., I, 153, pl. VII, fig. 2. STIMPSON, Jour. Bost. Soc. Hist., VI, p. 460 [20], 1857.

This species inhabits the whole coast of Oregon and Upper California. The expedition specimen is from Monterey, presented by officers of the Coast Survey.

43. CANCER MAGISTER Dana

Cancer magister DANA, U. S. Exploring Expedition, Crust., I, 151, pl. VII, fig. 1. STIMPSON, Jour. Bost. Soc. Nat. Hist., VI, p. 458 [18], 1857.

Very common in the harbor of San Francisco, Cal. Found on the western coast of North America from Sitka to Monterey.

44. CANCER PRODUCTUS Randall

PLATE IV, FIG. 5, 5*a*

Cancer productus RANDALL, Jour. Acad. Nat. Sci. Phila., VIII, 116. DANA, U. S. Exploring Expedition, Crust., I, 156, pl. VII, fig. 3. STIMPSON, Jour. Bost. Soc. Nat. Hist., VI, p. 461 [21], 1857.
Platycarcinus productus GIBBES, Proc. Am. Assoc., 1850, p. 177.

This species was described by Randall from young specimens, which differ much from the adult, both in proportions and markings. Dana also figures an immature specimen, and his description will scarcely apply to the adult, in which the teeth on the front and antero-lateral margin are sufficiently projecting and well separated.

The figure given in the plates represents an adult female.

It was taken in considerable numbers near San Francisco, Cal., where, next to *C. magister*, it is the most common species.

Genus ETISUS Leach

45. ETISUS CONVEXUS[1] Stimpson

PLATE V, FIG. 2

Etisus convexus STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 31 [29], 1858.

Carapax broad; proportion of length to breadth in the male, 1 : 1.47; in the female, 1 : 1.44; above strongly convex; areolets nearly as in *E. lævimanus*, but more prominent. Surface somewhat rugose toward the front and sides. Front slightly convex. Antero-

[1] *Etisus lævimanus* Randall.

lateral margin with five teeth, including the angle of the orbit; teeth rather prominent, with small, sharp apices; interspaces granulated. Chelopoda of moderate size, nearly smooth; upper surface of carpus and hand somewhat rough in the female; a small tooth at the inner angle of the carpus. Ambulatory feet compressed, and thickly fringed with hair on their edges; terminal joints rough, with spiniform granules, especially on the outer surface. Dimensions of a male: Length of carapax, 0.57; breadth, 0.84; of a female, length, 0.64; breadth, 0.92 inch.

It is allied to *E. lævimanus* of Randall and Dana, but is smaller, with the carapax more convex and the ambulatory feet more hairy. In our species the process from the basal joint of the antennæ quite reaches the orbit, while in *E. lævimanus* this is almost entirely excluded from the orbit.

Found at Simoda, Japan, under stones and among gravel in the littoral zone.

Genus CARPILIUS Leach

46. CARPILIUS MACULATUS (Linnæus) Milne Edwards

Cancer maculatus LINNÆUS.
Carpilius maculatus MILNE EDWARDS, Hist. Nat. des Crust., I, 382; Cuv. R. Anim., pl. XI, fig. 2. DANA, U. S. Exploring Expedition, Crust., I, 160.

Found at Tahiti. This and some other large kinds of crustacea are taken by the natives on the reefs at night. The light of a fire placed at the end of a long beam which projects from the bow of the canoe enables the fisherman to see the crabs out on their nocturnal predatory excursions. During the daytime they remain quiescent in their hiding places among the rocks.

According to Dana this species occurs also at the Paumotu, Raraka, Navigators, and Philippine Islands.

47. CARPILIUS CONVEXUS (Forskål) Rüppell

Cancer convexus FORSKÅL, Desc. anim., 88.
Carpilius convexus RÜPPELL, Krabben des rothen Meeres, p. 13, pl. III, fig. 2. MILNE EDWARDS, Hist. Nat. des Crust., I, 382, pl. XVI, figs. 9, 10. DANA, U. S. Exploring Expedition, Crust., I, 159, pl. VII, fig. 5.

The coloration is the same in all of the numerous specimens collected by the expedition, and differs from that represented in Dana's figure in the deeper hue of the reddish clouds, which also extend to the margin. There are two conspicuous deep red blotches on the gastric region, which are confluent behind and send off a branch on either side reaching to the orbit. A red patch on the hand, one on

the carpus, and one at each joint of the ambulatory feet. The dimensions of two specimens are as follows: Male, length of carapax, 2.3; breadth, 3.1; female, length, 2.4; breadth, 3.2 inches.

Found on coral reefs about low-water mark. Taken by us at Loo Choo and at Tahiti. It has also been found at most of the coral islands of the Pacific, among the East Indies, and in the Red Sea.

Genus LIOMERA Dana

This genus is here taken in a more extended sense than originally intended by Dana, so as to include his genus *Carpilodes* and the *Xantho obtusus* of De Haan. In our specimens of *L. lata* the fingers show more tendency to excavation at the tip than in that described by Dana, and are nearly the same as in *Carpilodes tristis*. In neither of these species, however, is the spoon-shaped cavity as well defined as in *Chlorodius*. This seems to point out the propriety of uniting the two genera of Dana, which, according to the statement of the author, differ only in the character of the fingers. In *Liomera obtusa,* which is intermediate in character between the two above mentioned, the fingers are more excavate than in either, and in a new species described below they are entirely acuminate.

As in allied genera, the third, fourth, and fifth joints of the male abdomen are united.

48. LIOMERA LATA[1] Dana

Liomera lata DANA, U. S. Exploring Expedition, Crust., I, 161, pl. VII, fig. 6.

This species is remarkable for its great breadth, which exceeds that of any other known crab. In our specimen the body is of a light blue color, the feet light red, the fingers black.

It was found at the Amakirrima Group, near Loo Choo, by Mr. L. M. Squires, of the steamer "Hancock."

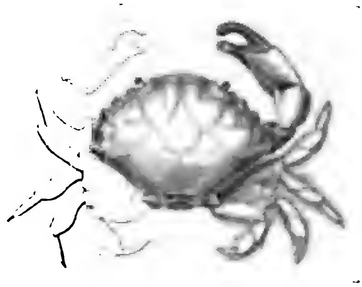
49. LIOMERA OBTUSA[2] (De Haan) Stimpson

Xantho obtusus DE HAAN, Fauna Japonica, Crust., p. 47, pl. XIII, fig. 5.
Liomera obtusa STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 32 [29], 1858.

Carapax rather less broad than in other species of the genus; proportion of length to breadth, 1 : 1.63. Anterior margin arcuate; posterior and postero-lateral sides straight, the former but little

[1] *Liomera cinctimana* (White).
[2] *Carpilodes venosus* (Milne Edwards).

1



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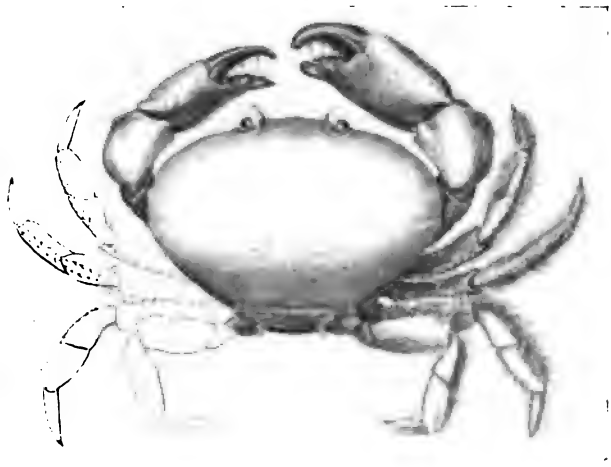

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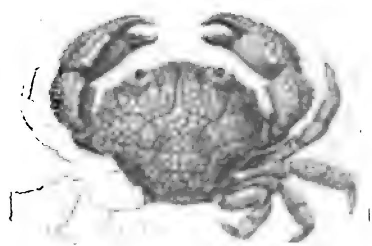
6



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CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

more than half the length of the latter. Antero-lateral margin regularly convex, four-lobed; the anterior two lobes but little wider and nearly as convex as the posterior two. Front slightly convex. Anterior two-thirds of upper surface areolate, the areolets nearly as in *C. tristis,* but more deeply defined, the longitudinal lines bisecting the lateral areas of the gastric region being particularly conspicuous. Surface minutely granular, as seen under a lens. Chelopoda of male smooth, rather short; carpus with a projecting lobe at the inner angle, behind which there is a small tooth. Excavations at tips of fingers not circumscribed within. Ambulatory feet smooth and glossy, somewhat compressed; penult and antepenult joints with bilobate upper margin. Color uniform deep scarlet; fingers brown, tipped with white; dactyli of ambulatory feet with a white annulation next their corneous tips. Dimensions of a male: Length of carapax, 0.49; breadth, 0.8; length of chelopod, 0.75 inch.

Easily distinguished from *L. tristis* by the peculiar waved character of the upper margin of the feet at the middle joints.

Found under stones on rocky ground, at low-water mark, at Ousima.

50. LIOMERA SUBACUTA Stimpson

PLATE V, FIG. 1

Liomera subacuta STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 32 [29], 1858.

Carapax transversely elliptical in shape; proportion of length to breadth, 1 : 1.61; surface smooth and glossy, except on the slightly depressed area above the front and orbits, where it is somewhat rugose with minute depressions. The areolets are mostly as in other species of the genus; the longitudinal sulci, however, which bisect the two large gastric areolets, are obsolète except anteriorly, where they form shallow grooves. The depressions at the anterior corners of the cardiac region are rather deep. The extreme lateral lobes (posterior two of the antero-lateral margin) are angular and form conspicuous teeth; the sulci separating them may be traced for a short distance only on the surface of the carapax, the posterior one being only half as long as the next. The remaining or anterior two-thirds of the antero-lateral margin is convex, and indistinctly divided into three scarcely projecting lobes, the middle one smallest. Front slightly projecting and deeply emarginated at the middle. The inner angle of the inferior orbital margin forms a tooth, which projects sufficiently to be easily seen from above. Chelopoda smooth; carpus with two small blunt teeth at its inner angle; hand with a groove on

the outer surface, parallel with and just beneath the upper margin: fingers sulcate, inner margins denticulated, tips sharp. Ambulatory feet glabrous, nearly smooth; superior edge of meros granulated or minutely denticulated.

Color in preserved specimens whitish, tinged with dusky orange. Fingers of a black color, not shading off toward the hand. Dimensions: Length of carapax, 0.57; breadth, 0.92 inch.

It has some resemblance to *L. obtusa* in its smoothness and general proportions, but its lateral lobes are acute and the fingers not at all excavated. It approaches *Xantho*, being less broad than other species of *Liomera*, to which genus it is referred from the character of the markings on the carapax.

Found at Loo Choo.

Genus LACHNOPODUS Stimpson

In this genus, as in allied forms, the carapax is smooth and posteriorly convex; the antero-lateral margin obtuse, with the teeth, or rather, lobes, but little prominent. At the external angle of the orbit the margin is more strongly puckered than in other genera of the family. The arrangement of the antennæ is as usual in *Carpilius*, *Xantho*, etc. The inner ramus of the internal gnathopoda is not furcate. In the hectognathopoda the ischium is marked with a longitudinal sulcus; the surface of the meros presents a depression near the internal angle, and the anterior margin of this joint is concave. The meros of all the feet is spinous above; the external surface of the hand is sulcated, and the last three joints of the ambulatory feet are thickly setose.

The character of the feet separates this genus from *Liomera* and *Liagora*, in which they are naked.

51. LACHNOPODUS RODGERSII Stimpson

PLATE V, FIG. 4

Lachnopodus Rodgersii STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 32 [30], 1858.

A single specimen only, a male, of this species was collected, in which the proportions of the carapax were, length to breadth as 1 : 1.49. Upper surface convex, smooth. On the antero-lateral margin the two exterior or lateral lobes only are well marked, forming small teeth, sufficiently prominent, although obtuse and distant; the separation between the first and second lobe is scarcely perceptible. Front a little prominent, and emarginate at the middle.

Orbits of moderate size; internal hiatus large. Surface of hectognathopoda smooth; inner margins thickly setose. Chelopoda unequal, the right being the larger; meros spinulose above; carpus with a glossy but somewhat uneven surface, and with two teeth at the inner angle, the upper one largest. Outer surface of hand with two or three longitudinal sulci, deepest in the smaller hand; ridges between the sulci transversely rugose. Ambulatory feet compressed; meros very slightly setose, with a single row of small spines along the superior crest and spinulose on the inferior edges; penultimate joint with two rows of spines above, beneath which there is a shallow excavation; last three joints setose with long yellow hairs.

Color reddish-white or orange in preserved specimens. Dimensions of carapax: Length, 1.04; breadth, 1.55.

This species is respectfully dedicated to Capt. John Rodgers, the commander of the expedition, to whose interest and zeal in forwarding the researches of the scientific corps the extent and value of the collections are in a great measure due.

It was taken on Bowers Shoal, in Gaspar Straits, during the survey prosecuted by Captain Rodgers in the steamer "John Hancock."

Genus ATERGATIS De Haan

52. ATERGATIS FLORIDUS[1] (Linnæus) De Haan

Cancer floridus LINNÆUS.
Cancer ocyroe MILNE EDWARDS, Hist. Nat. des Crust., I, 375.
Atergatis floridus DE HAAN, Fauna Japonica, Crust., p. 46. DANA, U. S. Exploring Expedition, Crust., I, 159, pl. VII, fig. 4.

Living specimens are of a dark yellowish-brown color above, with reticulating cream-colored blotches. Below white, tinged with cream color, and a little brownish in parts. Eyes leaden-blue, glossy. Fingers of a dark mahogany color.

Taken by the expedition at Loo Choo, among corals on the outer reefs, near low-water mark; also in Gaspar Straits.

The species also inhabits the seas of southern Japan and China (De Haan), and the Paumotu, Society, Friendly, and Fiji groups of islands (Dana).

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[1] *Atergatis ocyroe* (Herbst).

53. ATERGATIS INTEGERRIMUS (Lamarck) De Haan

Cancer integerrimus LAMARCK, An. sans vert., v, 273. MILNE EDWARDS, Hist. Nat. des Crust., I, 374.
Atergatis integerrimus DE HAAN, Fauna Japonica, Crust., p. 45, pl. XIV, fig. I. DANA, U. S. Exploring Expedition, Crust., I, 158.
Atergatis subdivisus ADAMS and WHITE, Voy. Samarang, Crust., p. 38, pl. VIII, fig. 3.

The living specimen was of a purplish-red color, with small bluish-white angular spots somewhat regularly distributed; below pale reddish. Fingers black; ambulatory feet of the same color as the body.

Found under a stone, at low-water mark, on a rocky shore at the eastern entrance of Hongkong harbor.

Genus DAÏRA De Haan

54. DAÏRA PERLATA (Herbst) De Haan

Cancer perlatus HERBST.
Cancer variolosus FABRICIUS, Suppl., p. 338.
Daïra perlatus DE HAAN, Fauna Japonica, Crust., p. 18.
Lagostoma perlata MILNE EDWARDS, Hist. Nat. des Crust., I, 387.
Daïra variolosa DANA, U. S. Expl. Exped., Crust., I, 203, pl. X, fig. 4.

Found at the Amakirrima Isles, near Loo Choo, by the officers of the steamer "John Hancock," Captain Stevens Dana reports it from the Samoan Isles. Milne Edwards gives the Atlantic Ocean as its habitat. If this be not a mistake, we may well doubt whether there may not be two species confounded under the name.

Dana rejects Herbst's name *perlata,* remarking that its meaning is not *pearly,* but *very broad.* All names where signification involves an error should undoubtedly be rejected, but in this case we have no reason for deciding with certainty that the latter meaning is not that actually intended by the author.

Genus ZOZYMUS Leach

55. ZOZYMUS ÆNEUS[1] (Linnæus) Leach

Cancer æneus LINNÆUS, LAMARCK.
Cancer floridus HERBST, FABRICIUS.
Zozymus æneus LEACH, DESMAREST, Consid. gen. Crust., p. 104; MILNE EDWARDS, Hist. Nat. des Crust., I, 385; DANA, U. S. Expl. Exped., Crust., I, 192, pl. X, fig. 3.
Ægle æneus DE HAAN, Fauna Japonica, Crust., p. 17.

In living specimens taken by us the color was blue above, with the tubercles red; eyes orange; sides of ambulatory feet shaded with

[1] *Zosimus æneus* (Linnæus).

orange. Beneath mostly white. Dimensions: Length, 2.14; breadth, 3.16 inches.

Found on the reefs, near low-water mark, at Loo Choo and at Tahiti. Dana reports it from the Paumotu, Samoan, and East Indian Islands.

Genus ACTEODES Dana

56. ACTEODES SPECIOSUS[1] Dana

Acteodes speciosus DANA, U. S. Expl. Exped., Crust., I, 198, pl. XI, fig. 4.

The dimensions of one of our specimens, a male, are as follows: Length of carapax, 0.44; breadth, 0.55 inch.

They were found among branches of madrepores drawn up from a depth of two or three fathoms near Hilo, Island of Hawaii. Dana's specimens are from the Samoan Islands.

57. ACTEODES BELLUS[2] Dana

Acteodes bellus DANA, U. S. Expl. Exped., Crust., I, 196, pl. XI, fig. 2.

This species has a resemblance to some species of *Liomera*. Our specimens are much more conspicuously granulated on the feet and anterior parts of the carapax than that figured by Dana.

The carapax and eyes in living examples are of an uniform bright scarlet color. Feet of the same hue but with the extremities white. Fingers brown, tipped with white. Dimensions of a male: Length of carapax, 0.33; breadth, 0.53 inch.

Found among madrepores drawn up from below low-water mark in the harbor "Port Lloyd," Bonin Islands.

58. ACTEODES AFFINIS[3] Dana

Acteodes affinis DANA, U. S. Exploring Expedition, Crust., I, 198, pl. XI, fig. 3.

Our specimens are from Ousima. Those of the U. S. Exploring Expedition from the Paumotu Group.

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[1] *Actæa speciosa* (Dana).

[2] *Actæa bella* (Dana).

[3] *Actæa affinis* (Dana).

59. ACTEODES TOMENTOSUS [1] (Milne Edwards) Dana

Zozymus tomentosus MILNE EDWARDS, Hist. Nat. des Crust., I, 385.
Acteodes tomentosus DANA, U. S. Expl. Exped., Crust., I, 197.

This crab is of an uniform dark-brown or purplish-brown color, almost black; the eyes blood-red; the antennulæ white at base; the fingers reddish. It may be observed at low water in great numbers on the level outer reefs of Loo Choo, taking refuge, when pursued, in the crevices of the rock. It was also found by the expedition at Ousima, at the Amakirrima Isles, and at Hongkong, China. According to Dana it is also common among the coral islands of the South Pacific and in the Sooloo Sea.

Genus ACTÆA (De Haan) Dana

60. ACTÆA PURA [2] Stimpson

PLATE V, FIG. 7

Actæa pura STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 32 [30], 1858.

Carapax rather narrow; proportion of length to breadth, 1 : 1.28. Surface of body and feet thickly covered above with granulated subconical tubercles, but everywhere clean and free from pilosity. The tubercles give the surface a hard porcellanous or crystalline appearance like that of some shells. The regions or areolets are not very prominent, being rendered somewhat indistinct by the crowding of the tubercles. Front with the two median lobes prominent. Antero-lateral margin strongly convex, obscurely quadrilobate, lobes tuberculated, the median tubercle in each being sharper and more prominent than the rest. Postero-lateral margin short, concave. Eyes large; outer margin of peduncle granulated. Pterygostomian surface granulous toward the outer margin, but becoming smoother toward the mouth. Hectognathopoda with the surface of the palpus and ischium smooth; inner margin of ischium and surface of meros granulated. Chelopoda large; upper and outer surface tuberculated like the carapax; fingers blackish, sulcate, with tuberculated ridges; their inner edges strongly toothed, tips blunt, curved inward. The tubercles of the ambulatory feet are somewhat smaller than those of the carapax, but more sharply granulous; on the dactyli they become subspiniform and are arranged in longitudinal rows. Inferior surface of the feet, and that of the sternum and abdomen,

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[1] *Actæa tomentosa* (Milne Edwards).
[2] *Actæa granulata* (Audouin).

where exposed, ornamented with smooth depressed granules or small tubercles. Surface of sternum between bases of chelopoda pitted.

Of a dark cream color, with purple-brown blotches. Dimensions of a male: Length of carapax, 0.61; width, 0.78 inch.

This species, although common at two or three localities, does not seem to have been described: at least we can find no description agreeing with it. It is an elegant species, with a surface like that of *Buccinum pappillosum* or *Monodonta reardonis*.

It is found at depths of 6, 10, and 20 fathoms, on muddy or shelly bottoms, and often among soft sponges. It occurred at Port Jackson, at Hongkong, and in the northern China Sea.

61. ACTÆA SUBGLOBOSA Stimpson

PLATE V, FIG. 5

Actæa subglobosa STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 33 [30], 1858.

This is a very thick, rounded species, and when seen in its usual position, with the feet closely retracted against the body, has an almost globose form. Its surface is everywhere densely villous, excepting certain exposed parts of the lower surface, where the coat seems to have been rubbed off. This is the case on the lower half of the hand, the outer surface of the last two joints of the ambulatory feet, and the more prominent portions of the sternum and abdomen. These parts come in contact with the surface of the cavity in which this sluggish crab habitually rests. The pubescence adheres very strongly to the body and is removed with considerable difficulty.

The carapax is much expanded anteriorly, strongly convex, with an even surface; proportion of length to breadth, 1:1.32. The areolets are scarcely distinguishable, even when the pubescence is removed—when the surface is seen to be sharply though somewhat sparsely granulated. The antero-lateral margin forms a regular curve, apparently smooth, but showing, upon close examination, three deep emarginations or fissures concealed by the villous coat; thus the margin is four-lobed, as in other species. Postero-lateral margin very short, shorter than the posterior margin, and strongly concave. Front with a very deep emargination; median lobes small and placed close together. Subhepatic region smooth, neither granulous nor sulcated; a lanose arch on either side of the mouth. Sternum granulous between the bases of the anterior two pairs of feet. The feet are smooth or only minutely granulous beneath the pubescence. Chelopoda very short and stout; fingers short, black, their white tips crossing each other.

The color in a preserved specimen is dark lemon-yellow above; naked parts below white. Dimensions of a male: Length of carapax, 0.6; breadth, 0.79; from front to lateral angle, 0.5 inch.

Dredged in Hongkong harbor. Also found in a cavity at the base of a mass of *Spoggodia* dredged from a shelly bottom, in 24 fathoms, in the China Sea, latitude 23°.

62. ACTÆA PILOSA Stimpson

PLATE V, FIG. 6

Actæa pilosa STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 33 [31], 1858.

The whole surface of the body and feet is hirsute with the exception of the tips of the fingers. The pubescence is rather less dense below than on the upper surface, where there are numerous setæ of greater length interspersed. Carapax convex; proportion of length to breadth, 1 : 1.33. Anterior margin nearly semicircular in outline and forming more than half the circumference of a circle. Postero-lateral margin strongly concave and about equaling the posterior margin in extent. The areolets of the surface may be easily traced, but are not strongly marked, the shallow sulci of separation being filled up with pubescence. The surface of the areolets is covered with sharp granules. Antero-lateral margin four-lobed, angle of orbit not included; the lobes distinct; first lobe small; third and fourth lobes depressed, subtriangular. Lobes of the front prominent, deflexed, with smooth edges. Subhepatic region minutely granulous, but not sulcated. Feet all strongly granulous and hairy on their exposed surfaces. In the chelopoda the fingers are hairy at their bases, longitudinally grooved, and 5-toothed on the inner edge. In the ambulatory feet the antepenult joint is grooved above.

Dimensions: Length of carapax, 0.42; breadth, 0.56 inch.

This species has much resemblance to *A. hirsutissima,* but the carapax is not so deeply areolated, and the subhepatic region is not grooved with sulci proceeding from the notches of the antero-lateral margin.

Taken at Hongkong, China.

Genus XANTHO Leach

63. XANTHO TRUNCATA De Haan

Xantho truncatus DE HAAN, Fauna Japonica, Crustacea, p. 66, pl XVIII, fig. 4.

In adult specimens collected by us the anterior tooth of the four on the antero-lateral margin is blunt and inconspicuous. The dimen-

sions of a male specimen are: Length of carapax, 0.62; breadth, 0.84 inch.

Found among stones above low-water mark at Simoda, Japan.

64. XANTHO PARVULA[1] (Fabricius) Milne Edwards

Cancer parvulus FABRICIUS, Ent. Syst., II, 451.
Xantho parvulus MILNE EDWARDS, Hist. Nat. des Crust., I, 395. DANA, U. S. Exploring Expedition, Crust., I, 170.

A species of *Xantho* agreeing with descriptions of the above species was dredged in the harbor of Porto Praya, Cape de Verde Islands, among nullipores and sand, at a depth of 12 fathoms.

Genus XANTHODES Dana

In addition to the characters of this genus given by Dana, we may mention that another prominent distinctive mark of the species belonging to it is the shortness or little prominence of the front, which scarcely projects beyond the orbits, while in *Xantho* proper it is considerably protruded.

65. XANTHODES ELEGANS[2] Stimpson

PLATE V, FIG. 3

Xanthodes elegans STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 33 [31], 1858.

Carapax distinctly but not deeply areolate, smoother posteriorly; proportion of length to breadth, 1 : 1.43. Surface glossy but uneven, with projections toward the anterior margins. Antero-lateral margin with four sharp subpapilliform teeth, besides the angle of the orbit, which is not prominent. Orbits moderately large, with three or four small tooth-like projections on the margins. Subhepatic region strongly convex, smooth. Chelopoda with the carpus ornamented with scabriform tubercles; outer surface of hand sulcate, the ridges between the sulci tuberculated; fingers black. Ambulatory feet hairy; antepenult joint rather conspicuously grooved.

Dimensions of a male: Length of carapax, 0.42; breadth, 0.6 inch.

Taken at Simoda, Japan.

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[1] *Xantho parvulus* Dana, which is a synonym of *Xanthias melanodactylus* (A. Milne Edwards); not *Xantho parvulus* Milne Edwards, which is a species of *Eurypanopeus*.

[2] *Xanthias elegans* (Stimpson).

Genus EUXANTHUS Dana

66. EUXANTHUS MELISSA[1] (Herbst) Stimpson

PLATE VI, FIG. 2

Cancer melissa HERBST, Naturg. der Krabben und Krebse, III, 7, pl. LI, fig. 1.
Atergatis melissa WHITE, Cat. Brit. Mus., 1847, p. 14.
Euxanthus melissa STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 33 [31], 1858.

The only specimen of this species found by us is a male, the dimensions of which are: Length of carapax, 1.61; breadth, 2.54 inches. It was taken at Gaspar Island, in the straits of the same name, by Mr. L. M. Squires, of the steamer "John Hancock."

Euxanthus nitidus of Dana (loc. cit., I, 174, pl. VIII, fig. 9) is not improbably the young of this species. The characters in which the female specimen upon which that species was founded differs from the type are only those which might well be the result of differences of age or sex.

Genus POLYCREMNUS Gerstæcker

This genus was recently established by Gerstæcker (Archiv für Naturgeschichte, XXII, 120) for the reception of the *Cancer ochtodes* of Herbst, a species which was referred to *Panopeus* by Milne Edwards and to *Galene* by Adams and White. Its generic distinctness is, however, sufficiently apparent, and we had named and described it in our notes before seeing the paper in the Archiv. The description then drawn up may without disadvantage be presented here, as it details some characters not mentioned by Gerstæcker.

Carapax subhexagonal, the lateral angles truncated and bidentate, the teeth being equal. Front rather narrow, considerably produced, emarginate at the middle. Antennæ with the basal article joined to a process from the frontal margin, as in *Xantho,* the movable portion placed in the hiatus of the orbit. Antennulæ oblique. Orbit with three closed fissures at the exterior margin, two above and one just beneath the external angle. The orbits are directed obliquely upward and not forward, so that the whole inferior margin, as well as the sharp inner angle, may be seen from above when the eyes are retracted. Epistome of considerable length; as long as in most *Parthenopidæ.* Meros of hectognathopoda broader than long, trun-

[1] *Euxanthopsis exsculpta* (Herbst).

cate, but not notched at the insertion of the carpal joint. The chelopoda are tuberculated; hands broad, with short fingers. Ambulatory feet slender; dactyli pubescent. Abdomen of the male slender, seven-jointed, the third, fourth, and fifth joints not soldered, the terminal joint very long and slender.

It is allied to *Halimede* in shape and in the characters of the front, antennæ, gnathopoda, and abdomen, but the margin of the orbit is without hiatus, and has no inner fissure of the inferior margin.

67. POLYCREMNUS VERRUCIFER Stimpson

PLATE VI, FIG. I

Polycremnus verrucifer STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 33 [31], 1858.

This species differs from *P. ochtodes* Gerstæcker (*Cancer ochtodes,* Herbst, Crust., I, 158, pl. VIII, fig. 54), in its smaller size and somewhat narrower carapax, the surface of which is also smoother anteriorly. The tubercles of the chelopoda are less capitate in shape and more numerous.

Our specimens agree well in size, color, and general appearance with the figure in the Zoölogy of the Voyage of the Samarang (Crust., pl. x, fig. 2). But they differ in some points mentioned below; and even if identical, we can scarcely suppose the species of Adams and White to be the *Cancer ochtodes* of Herbst, to the young of which it is referred by the English authors. It is constantly smaller, while most of the numerous specimens examined have every appearance of being adults.

In the specimens now under examination the teeth of the antero-lateral margin are granulated below, and there are two minute teeth on the postero-lateral margin behind the large teeth. There is a granulated protuberance on each side just above the lateral extremity of the posterior margin. The carpus and hand are more verrucose than is represented in the figure of Adams and White, much of the outer, as well as the upper, surface being covered with tubercles. The ambulatory feet are somewhat scabrous above, particularly on the meros joint; their sides are smooth; the last two joints are hairy. The abdomen is much more slender, and the third joint more elongated, than in the figure cited. The color in life was yellowish-brown, mottled. Dimensions of a male: Length of carapax, 0.63; breadth, 0.76 inch; ratio, 1 : 1.2.

This species is not uncommon on bottoms of shelly mud, at the depth of four or five fathoms, near Hongkong, China.

Genus HALIMEDE De Haan

In this genus the prælabial area is smooth, with no indication of a ridge defining the efferent passage. The orbits have two fissures above and two below, the external inferior fissure forming an hiatus as well marked as in *Panopeus*.

68. HALIMEDE FRAGIFER De Haan

Halimede fragifer DE HAAN, Fauna Japonica, Crust., p. 47, pl. XIII, fig. 4.

The color in life is, above bluish-gray and white, mottled; below paler.

Dredged from a shelly bottom, in 10 fathoms, near Hongkong, China.

Genus CHLORODIUS Leach

69. CHLORODIUS CYTHEREA[1] Dana

Chlorodius cytherea DANA, U. S. Exploring Expedition, Crust., I, 213, pl. XII, fig. 2.

Taken by us at the Sandwich Islands and at Ousima.

70. CHLORODIUS NIGER[1] (Forskål) Rüppell

Cancer niger FORSKÅL.
Chlorodius niger RÜPPELL, Krabben des rothen Meeres, p. 20, pl. IV, fig. 7. MILNE EDWARDS, Hist. Nat. des Crust., p. 401. DANA, U. S. Exploring Expedition, Crust., I, 216, pl. XII, fig. 5.

In living specimens the color is uniform blue-black above; below bluish; articulations of the feet yellowish.

Found by us at the Bonin Islands, at Loo Choo, and at Tahiti, always among living corals, below low-water mark. It is also found in the Red Sea (Rüppell), in the Sooloo Sea, at Mangsi, the Fiji Islands, Tongatabu, Wakes Island, and Upolu (Dana).

71. CHLORODIUS MONTICULOSUS[2] Dana

Chlorodius monticulosus DANA, U. S. Expl. Exped., Crust., I, 206, pl. XI, fig. 9.

Of a purplish-brown color in life, variegated with white or yellowish-white. The fingers, and sometimes the whole hand, are deep

[1] *Chlorodiella niger* (Forskål).
[2] *Phymodius ungulatus* (Milne Edwards).

brown. Eyes always red. The young are often dark olive with a yellowish pubescence.

Besides the sharp tubercles, a character distinguishing this species from *C. ungulatus* may be found in the front, which in the latter species is deeply sinuous, the median lobes projecting, while in the *monticulosus* it is blunt, often bimarginate, and projects but little.

Found among corals at slight depths at Loo Choo, at the Bonin Islands, and at Tahiti. It also occurs at the Fiji and Navigator Islands, and in Balabac Straits (Dana).

72. CHLORODIUS DENTIFRONS[1] Stimpson

PLATE VI, FIG. 5

Chlorodius dentifrons STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 34 [33], 1858.

Carapax anteriorly expanded; proportion of length to breadth, 1 : 1.35. The anterior three-fourths of the surface is well areolated; the longitudinal sulci are deeper than those having a transverse direction, particularly on the gastric region, where the two grooves proceeding backward from the front and dividing in two the lateral lobes of this region, are strongly marked, and reach nearly to the posterior margin of the lobes. The more protuberant parts of the areolets, particularly of the lateral ones, are strongly granulated. The transverse raised line crossing the carapax from one lateral tooth to the other is well marked in this species, convex behind, and ciliated. This line marks off the smoother posterior part of the carapax, which constitutes rather less than a fourth part of the whole length. There is also a slight ridge just above and parallel with the posterior margin; this is interrupted at the middle. Antero-lateral margin with four small, sharp equidistant teeth, besides the angle of the orbit. Front rather narrow, considerably projecting, and quadridentate; the lateral teeth a little smaller than the middle ones. Orbital margin with deeper and more strongly marked fissures than are seen in other species, giving it a toothed appearance. Chelopoda of rather small size, even in the male; upper surface rugulose; carpus with two or three small teeth above; hand with one small basal tooth and three or four minute ones along the upper margin; outer surface of hand covered with minute transverse granulose rugæ, as in *C. exaratus;* fingers well curved toward their excavated tips, very little gaping, small-toothed within, and brown in color, the brown of

[1] *Etisodes electra* (Herbst).

the thumb extending on to the hand for some little distance. Ambulatory feet conspicuously hairy; their sides smooth. Dimensions of a male: Length of carapax, 0.33; breadth, 0.45 inch.

It has considerable resemblance to *Cancer electra* Herbst (pl. LI, fig. 6), but the frontal teeth are less prominent and the greatest width is at the penult, and not at the last antero-lateral tooth.

This species was taken at Loo Choo.

73. CHLORODIUS EXARATUS[1] Milne Edwards

PLATE VI, FIG. 3-4, 6-9

Chlorodius exaratus MILNE EDWARDS, Hist. Nat. des Crust., I, 402; Illust. Cuv., pl. XI, fig. 3. HOMBRON and JACQUINOT, Voy. au Pole Sud, pl. II, fig. 3. DANA, U. S. Expl. Exped., Crust., I, 208.

Chlorodius sanguineus MILNE EDWARDS, Hist. Nat. des Crust., I, 402. DANA, U. S. Expl. Exped., Crust., I, 207, pl. XI, fig. II.

Xantho affinis DE HAAN, Fauna Japonica, Crust., 48, pl. XIII, fig. 8.

Xantho lividus DE HAAN, *l. c.*, 48, pl. XIII, fig. 6.

Xantho distinguendus DE HAAN, *l. c.*, 48, pl. XIII, fig. 7 (?).

This is the most common of the numerous species of *Chlorodius* found in the eastern seas, and large numbers of specimens were collected by the expedition at different places on the shores of China and at the Japanese and the Pacific islands. It is only after a long and careful study of these specimens that we have arrived at the results set forth in the above synonymy.

That the *Chlorodius exaratus* of Milne Edwards is a very variable species, and is so considered by the carcinologists at Paris, will be evident from a comparison of the figure in the illustrated edition of the "Règne Animal" with that in the "Voyage au Pole Sud." But one would scarcely be prepared to find so much variety in the character of the surface, the number and shape of the lateral teeth, and the sculpture of the feet, as we see in the present instance, these characters being in other genera and species of the highest specific importance. The varieties described below, however, are found to run into each other in all the characters which at first sight strike the examiner as specific, and several of them are often found living together under circumstances which do not fail to impress the collector with the idea that they are one and the same species.

We are first led to question the distinctness of *C. sanguineus* by finding in a number of specimens from Loo Choo the supplementary tooth posterior to the lateral one, gradually becoming smaller and

[1] *Leptodius exaratus* Milne Edwards.

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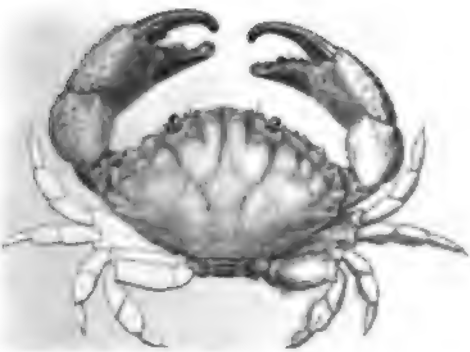

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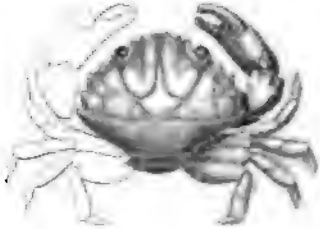

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CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

at last entirely disappearing, while in other characters the specimens remain exactly the same. And the figure of *C. exaratus,* in the "Voyage au Pole Sud," certainly presents the characters usually assigned to *C. sanguineus.* Among our specimens it is not difficult to find forms agreeing with De Haan's *Xantho lividus* and *X. affinis;* and these are so connected by intermediate forms that they cannot be specifically separated. Every degree of extent in the front and in the hiatus of the fingers, between the extremes represented by these two varieties, may be found among our specimens. The *Xantho distinguendus* certainly appears at first entirely distinct, the granulation of the carapax and hands, and particularly the sculpture or erosion of the ambulatory feet, seeming to be characters which it would be in vain to seek for in any variety of *C. exaratus.* But we have before us specimens of this form from Hongkong which show gradations toward the type. In some of these the carapax is rather broad, with little or no granulation and a protruded front. In others the granulation of the hand disappears, while that of the carapax remains the same. In others all granulation disappears, and among all these specimens there are some which possess the supplementary tooth, while in others it is wanting.

Future observers, aided by a still greater number of specimens than is now accessible, may succeed in finding constant characters upon which good species may be founded, but the present indications certainly require us to regard as varieties the several forms now to be described.

Var. *a,* SANGUINEUS

With a distinct supplementary tooth, formed by the division by a sulcus of the posterior edge of the lateral tooth of the margin; this is much more distinct in the adult than in the young. The antero-lateral teeth are sufficiently prominent, anterior ones blunt. Front much undulated, rather narrow (in extent just half that of the antero-lateral margin), and scarcely protruded beyond the edge of the orbit. Surface of carapax areolate, areolets rather smooth and glossy, shining. Upper and outer surface of chelopoda with reticulating rugæ. Pincers sometimes much curved, moderately gaping, inner edges well toothed; color black, tips white. Ambulatory feet smooth, edges hairy; penult and antepenult joints obsoletely grooved above; dactyli granulose.

Found at the Sandwich Islands and at Loo Choo.

Var. *b*, RUGOSUS

PLATE VI, FIG. 4

With the characters of the preceding, except that the areolets of the carapax, and also the antero-lateral teeth, are much more sharply prominent and rugose. The reticulating rugæ of the chelopoda are granulose, and there is a small tuft of setæ in each of the cup-shaped depressions at the tips of the fingers. This is the largest variety we have met with.

Found at the Bonin Islands.

Var. *c*. PICTUS

PLATE VI, FIG. 6

Supplementary tooth wanting. Surface of carapax smooth posteriorly; areolets but little prominent except toward the antero-lateral margin. Antero-lateral teeth broad, triangular, not much projecting. Front somewhat broader than in var. *sanguineus* and protruding a little beyond the orbits. Chelopoda short, rugulose, rugæ minutely granulated. Pincers rather short, black, well toothed and contiguous within. Ambulatory feet as in var. *sanguineus*, except that the dactyli are less granulose. Color yellowish, symmetrically clouded above with olivaceous, inclining to brown on the carapax and to red on the feet. Dimensions: Length of carapax, 0.53; breadth, 0.81 inch.

Found at Simoda, Japan.

The variety called *Xantho affinis* by De Haan differs from the *pictus* in its smoother hand and gaping fingers.

Var. *d*, LATIFRONS

Supplementary tooth wanting. Carapax less broad than in other varieties, rather convex, smooth posteriorly; areolets not strongly prominent, but with deep transverse sulci; surface conspicuously rugose and granulated. Antero-lateral teeth angular but not much projecting. Front not protruding, and very broad, equaling in extent the antero-lateral margin excluding the lateral tooth. Chelopoda rugulose; outer surface of hand maculate with small circular red spots. Pincers black, contiguous, toothed. Ambulatory feet as in var. *pictus*. Dimensions: Length of carapax, 0.45; breadth, 0.70 inch.

Found at Loo Choo.

The variety called *X. lividus* by De Haan differs from the *latifrons* only in having white fingers.

Var. *e*, TYPICUS

A variety which may be considered typical, agreeing perfectly with Milne Edwards's original description, and showing in a moderate degree nearly all the characters which are excessively developed in other varieties. It differs from the var. *latifrons* in its narrower front and somewhat gaping pincers.

Found at Ousima, and at other islands in the Chinese and Japanese seas.

Var. *f*, ACUTIDENS

PLATE VI, FIG. 7

Supplementary tooth waiting. Carapax less broad than in ordinary varieties. Areolets sharply prominent. Antero-lateral teeth strongly projecting and acuminate (*i. e.*, with concave sides), the anterior ones sharper than usual. Front narrow, not much protruded, deeply sinuous, almost quadridentate. Chelopoda stout, rugulose; fingers black, somewhat gaping, not strongly toothed within. Ambulatory feet as in var. *pictus*, but more hairy. Dimensions: Length, 0.532; breadth, 0.8 inch.

Found at Loo Choo.

Var. *g*, CUPULIFER

PLATE VI, FIG. 8

Carapax as in var. *acutidens* except that the edges of the areolets are more granulous, and the antero-lateral teeth are more prominent. Chelopoda as in var. *rugosus;* fingers somewhat gaping, their tips well excavated, forming large deep spoon-shaped cavities or cups. Dimensions: Length, 0.45; breadth, 0.66 inch.

Found at the Bonin Islands.

Var. *h*, LATUS

PLATE VI, FIG. 9

Carapax very broad. Antero-lateral teeth strongly prominent, acuminate, their edges with large granules appearing as if denticulated. Surface smooth posteriorly. Areolets not prominent; their surfaces minutely granulose and slightly hairy. The transverse raised line connecting the lateral teeth is distinct, and strongly granulose at the point where it bifurcates to form the supplementary tooth. Front narrow, strongly sinuous, or quadridentate; somewhat protruded. Chelopoda transversely rugulose, and minutely granu-

lated; fingers black, much gaping, within dentate with very small distant teeth. Ambulatory feet as in the preceding varieties. Dimensions: Length, 0.45; breadth, 0.73 inch.

Found at Hongkong.

Var. *i*, GRANULOSUS

PLATE VI, FIG. 3

No supplementary tooth. Carapax broad as in the preceding variety, but with triangular, non-acuminate antero-lateral teeth. Transverse line connecting lateral teeth, distinct. Transverse edges of areolets conspicuously granulated. A granulated ridge, interrupted at the middle, just above and parallel with the posterior margin. Front narrow, strongly protruding. Hands somewhat grooved above; with the outer surface covered with large granules; fingers black, somewhat gaping, with large teeth. Ambulatory feet granulous above; penult and antepenult joints broadly grooved above as if eroded; dactyli granulose and hairy. Dimensions: Length, 0.525; breadth, 0.79 inch.

Found at Hongkong.

74. The variety called *Xantho distinguendus* [1] by De Haan differs from var. *granulosus* only in its narrower form, less protruded front, and more granulous meros joint of the feet.

In all the varieties the black color of the thumb is extended upon the hand, and circumscribed by a waved line having an inward and downward direction.

Chlorodius floridanus Gibbes, is by some authors considered a variety of *C. exaratus*. But a constant distinctive character may be found in the thickening or downward protrusion of the median lobes of the front, which is seen in all examples of the American species.

Chlorodius exaratus inhabits stony ocean shores, at or above low-water mark.

75. CHLORODIUS GRACILIS [2] Dana

Chlorodius gracilis DANA, U. S. Exploring Expedition, Crust., I, 210, pl. XI, fig. 13.

Carapax smooth, areolets not prominent and often indistinct; surface minutely granulose toward the antero-lateral margins. Antero-lateral teeth five in number including the angle of the orbit; they

[1] *Leptodius distinguendus* (de Haan).

[2] *Leptodius gracilis* Dana.

are broad, very slightly projecting; the posterior two angular with their posterior sides six times as long as their anterior sides. Front of moderate width; the interorbital breadth being more than half the width of the carapax. Surface of chelopoda minutely rugulose. Pincers black; the black color of the thumb not extending on to the hand; teeth of inner margins strong. Ambulatory feet as in the typical variety of *C. exaratus*, but less hairy. The abdomen is also as in the last mentioned species.

Color light reddish. Dimensions of a male: Length of carapax, 0.43; breadth, 0.65 inch.

The description is taken from a Chinese specimen. Those from the Japanese islands agree more exactly with Dana's description, and a comparison with the original specimens shows them to be the same.

This may finally prove to be a smooth variety of *C. exaratus*. The specimens all show a system of rugosities upon the chelopoda of the same kind as in that species, although so nearly obsolete that the surface appears smooth. But the present indications, particularly the want of prominence in the antero-lateral teeth, lead us to consider the form specifically distinct.

It was taken by us on the coast of China, near Hongkong, under stones on coarse sand, at low-water mark; also at Ousima and Kikaisima.

76. CHLORODIUS CAVIPES[1] Dana

Chlorodius cavipes DANA, U. S. Exploring Expedition, Crust., I, 212, pl. XII, fig. I.

In some of our specimens the superior crest of the meros in the ambulatory feet is bifurcated near the outer extremity, enclosing an additional small triangular cavity.

This species approaches *Acteodes* in form, and is one of the connecting links between the Chlorodinæ and the Zozyminæ. It might well be generically separated from a genus containing such forms as *C. ungulatus* and *monticulosus*.

Taken at Port Lloyd, Bonin Islands.

Genus PILODIUS Dana

In this genus the outer margin of the orbit is more nearly entire than in any other belonging to the group.

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[1] *Leptodius cavipes* Dana.

77. PILODIUS NIGROCRINITUS Stimpson

PLATE VII, FIG. 1

Pilodius nigrocrinitus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 34 [32], 1858.

The entire upper surface of the body and feet is covered with short setæ, among which many of a black color are conspicuously distributed; there are also longer ones of a yellow color sparingly interspersed. Carapax broad, well areolated; separating grooves deep. Surface of areolets somewhat scabrous. Antero-lateral margin convex, teeth slightly prominent, rounded and denticulated. The front is less prominent than usual and its median emargination is inconspicuous. In the chelopoda the carpus and hand are rough with spiniform granules. In the ambulatory feet the meros is serrated above.

One specimen only was taken, a female, the dimensions of which are: Length of carapax, 0.28; breadth, 0.41 inch; ratio, 1 : 1.46.

It is closely allied to *P. pilumnoides,* but is broader; the antero-lateral margin is convex instead of concave, and its denticulated teeth are rounded, having no central principal denticle, and there is no tooth at the inferior extremity of the penult joint of the feet. It is not improbably the same as *P. pilumnoides* Dana, but cannot be that of Adams and White.

Taken at Simoda, Japan.

78. PILODIUS GRANULATUS Stimpson

PLATE VII, FIG. 2

Pilodius granulatus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 34 [32], 1858.

Carapax broad; proportion of length to breadth in the male, 1 : 1.5. Antero-lateral margin a little shorter than the postero-lateral. Upper surface of carapax well areolated; surface of areolets strongly granulated or tuberculated and pubescent. Teeth of the antero-lateral margin four in number, excluding the angle of the orbit. They are small, denticulated, and acute (particularly the first one), the median denticle in each being sharply prominent and curving forward. Front, orbits, etc., nearly as in *P. pubescens* and *pilumnoides.* Chelopoda tuberculated; carpus armed with sharp tubercles rather larger than those of the hand, and with two small, very sharp teeth or spines at its inner angle; hand with tubercles

somewhat distantly arranged in longitudinal rows; fingers sulcate, the ridges tuberculated at base. The exposed upper surfaces of the ambulatory feet are granulose and thickly pubescent.

Colors: The upper surface is variegated with purple-brown and buff. Fingers reddish-brown. Hand in the male a broad encircling band of brown near the bases of the fingers. Dimensions of a male: Length of carapax, 0.29; breadth, 0.44 inch. Of a female: Length, 0.33; breadth, 0.5 inch.

This species differs from *P. pubescens* in the broader abdomen of the male, the extremity of which is bluntly rounded. From *P. pilumnoides* it differs in the absence of denticulation at the superior edge of the meros joint of the feet.

Found on madrepores, drawn up from a depth of 1 or 2 fathoms, in a bay on the outer side of Hongkong Island.

Genus CYMO De Haan

The crabs of this genus are easily recognized by their depressed, suborbicular form and rough, hairy surface, which is almost always obscured by sordes. They have some affinity to the *Trapeziæ* in general appearance and in their habits. The two known species are always found together, and are common on coral everywhere in the warmer latitudes of the Pacific Ocean.

79. CYMO MELANODACTYLUS De Haan

Cymo melanodactylus De Haan, Fauna Japonica, Crust., p. 22 (no descr.). Dana, U. S. Expl. Exped., Crust., I, 225, pl. XIII, fig. 1.

This species is of a dirty buff color, the eyes purplish-brown, the fingers black.

The characters of the front, etc., mentioned by authors as distinguishing this species from *C. andreossyi* are unreliable on account of their variation. In fact, it would seem impossible to separate the two species from characters derived from the carapax alone. The chelopoda, however, afford some good distinctive marks. In *C. melanodactylus* the granules of the outer surface of the hand are arranged in longitudinal rows, those of the middle row and of a row near the upper edge being larger than the others; those of the rows near the upper edge subspiniform and sharp. There are generally numerous *red* granules on the upper surface of the hand, but none on the outer surface, as in *C. andreossyi*. The fingers are black, with the basal half strongly granulated.

Found on madrepores hooked up in a bay on the east side of Hongkong Island; also at the Bonin Islands. Dana reports it from the Fijis.

80. CYMO ANDREOSSYI (Savigny) De Haan

Pilumnus andreossyi SAVIGNY, Descr. de l'Egypte, Crust., p. 86, pl. v, fig. 5.
Cymo andreossyi DE HAAN, Fauna Japon., Crust., p. 22. DANA, U. S. Expl. Exped., I, 225, pl. XIII, fig. 2.

In this species the fingers are thick and white and but little granulous at base. The granules of the outer and upper surface of the hand are sharply prominent and irregularly crowded, without any tendency to arrangement in rows; among them a few red ones are scattered.

It was found by us at the Bonin Islands.

Genus OZIUS Milne Edwards

81. OZIUS TRUNCATUS Milne Edwards

Ozius truncatus MILNE EDWARDS, Hist Nat. des Crust., I, 406, pl. XVI, fig. 11. DANA, U. S. Expl. Exped., Crust., I, 230, pl. XIII, fig. 4.

The color in life is, above purplish-brown, minutely mottled with white; below paler, inclining to reddish.

Taken in the harbor of Sydney (Port Jackson), Australia, under stones above low-water mark.

82. OZIUS FRONTALIS[1] Milne Edwards

PLATE VII, FIG. 4

Ozius frontalis MILNE EDWARDS, Hist. Nat. des Crust., I, 406.

The crab which is referred with much doubt to the above-quoted species of Milne Edwards is of a dark olive or yellowish-brown color in life; pincers black. Dimensions of a female: Length of carapax, 0.57; breadth, 0.97 inch; ratio 1:1.7.

Found under stones on coarse sandy shores above low-water mark in the harbor of Hongkong, China; also at Ousima and Kikaisima.

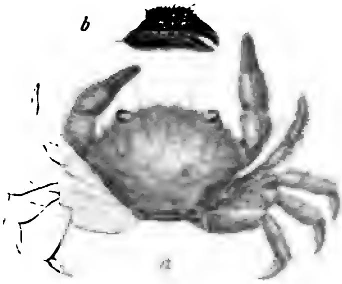
83. OZIUS RUGULOSUS Stimpson

PLATE VII, FIG. 6

Ozius rugulosus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 34 [32], 1858.

Carapax somewhat convex; proportion of length to breadth, 1:1.5. Surface anteriorly rugose and granulose. Front armed with four strong rounded teeth. Antero-lateral margin six-toothed, the pos-

[1] *Epixanthus frontalis* (Milne Edwards).



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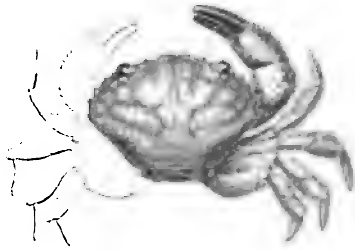

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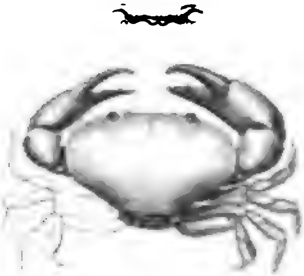

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terior tooth being small and supplementary to the fifth; anterior two teeth very large but much less prominent than the others. Postero-lateral margin short and concave. Inferior surface of the body tomentose. Subhepatic and subbranchial regions of the carapax granulated. Meros of hectognathopoda notched at the anterior margin. Chelopoda unequal in size, the right largest, rugose above with reticulating granular ridges; larger hand with nearly smooth outer surface, fingers gaping and toothed as in *O. truncatus;* smaller hand with the outer and under surface rugose and tomentose, fingers slender, small-toothed, and in contact nearly throughout their length, the tips curved inward. Ambulatory feet granulous above; last three joints densely tomentose, except the tips of the dactyli, which are smooth and glossy, red, and crystalline in appearance.

Color above dark olive, minutely punctate with yellow; below, the pubescence is buff-colored. Larger hand of a clear dark-red color; pincers black. Dimensions of a male: Length of carapax, 0.85; breadth, 1.27 inches. Of a female: Length, 1.25; breadth, 1.86 inches.

Found under stones not far below high-water mark, among gravel, in the harbor of Port Lloyd, Bonin Islands.

Genus PSEUDOZIUS Dana

84. PSEUDOZIUS MICROPHTHALMUS Stimpson

PLATE VII, FIG. 3

Pseudozius microphthalmus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 35 [32], 1858.

Carapax very broad; proportion of length to breadth, 1:1.7. Upper surface smooth, punctate, and perfectly flat except near the deflected anterior margin, where it is somewhat rugulose, as if slightly eroded. Two impressed lines or sulci on the gastric region, which unite anteriorly and lead toward the frontal emargination, there becoming, however, shallow and nearly obsolete. The inter-antennary front is rather narrow, not projecting, and slightly waved. Teeth of antero-lateral margin nearly obsolete, even less prominent than in *P. planus;* edge obtuse. Orbits and eyes very small. Chelopoda rather short and stout; upper surface minutely and crowdedly punctate; fingers short, black. Ambulatory feet hairy beneath; dactyli thickly pubescent. Dimensions of a female: Length of carapax, 0.43; breadth, 0.72 inch.

This species approaches very closely to *P. planus* Dana, U. S.

Expl. Exped., Crust., I, 233, but the carapax is flatter, the interantennary front is narrower, and the eyes smaller.

Found at the Bonin Islands.

Genus SPHÆROZIUS Stimpson

This genus is separated from *Pseudozius* Dana to include his *P. dispar* and one other species. They are characterized by a globose form, narrow carapax, and by the continuity of the frontal and supraorbital margins, which are not separated by a notch, as in most other genera of cancroids. The wide internal hiatus of the orbit is filled by the outer antenna.

85. SPHÆROZIUS NITIDUS Stimpson

PLATE VII, FIG. 5, 5*a*

Sphærozius nitidus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 35 [32], 1858.

Body small, subglobose; carapax about four-fifths as long as broad, convex, smooth and shining, not areolate, but with an inconspicuous longitudinal sulcus on the gastric region, reaching to the front, which is emarginated and somewhat projecting at the middle. Frontal margin continuous with upper margin of orbit. Teeth of antero-lateral margin four in number, small but acute. Chelopoda unequal, robust, rounded; outer and upper surface of hands granulous; carpus smooth; fingers nearly black and longitudinally grooved on their outer sides. Ambulatory feet somewhat hairy.

Color in life: Carapax dark gray; feet punctate with black. Dimensions of a female specimen: Length of carapax, 0.235; breadth, 0.29 inch.

Allied to *Pseudozius dispar* Dana, *loc. cit.*, I, 235, pl. XIII, fig. 9, but distinguished from it by its sharper antero-lateral teeth and by the want of tubercles on the hands.

Only one specimen of this species occurred to us; this was found in a cluster of *Spoggodia* which grew on a rock just below low-water mark at the island of Hongkong, China.

Genus HETEROPANOPE Stimpson

A well-marked group of cancroids is found in the eastern seas, the species of which hitherto discovered have been referred to the genus *Panopeus,* to which they have much resemblance. This genus

is, however, as far as now known, exclusively American, and the oriental forms present certain distinctive characters which cannot be regarded as otherwise than of generic importance.

The carapax is generally like that of *Panopeus,* the sharp, toothed antero-lateral margin being shorter than the postero-lateral; but the front is deflexed, with the median lobes generally prominent. The antero-lateral teeth are in general peculiarly cut, with convex sides; and they are often irregular in size. The hiatus of the infero-exterior angle of the orbit is small and inconspicuous. The hecto-gnathopoda are generally not in contact along their inner margins; and the ridge of the palate, defining the efferent canal, is sharply prominent at the buccal margin. In the abdomen of the male the joints are all distinct, the third, fourth, and fifth not being soldered, as is usually the case in allied genera.

This genus will include *Panopeus dentatus, P. caystrus,* and *P. formio* of Adams and White (Voy. Samarang, Crust., pp. 41, 42), and the following new species.

86. HETEROPANOPE GLABRA Stimpson

PLATE VIII, FIG. 1

Heteropanope glabra STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 35 [33], 1858.

Carapax transverse; proportion of length to breadth, 1 : 1.55; convex, broad anteriorly; upper surface smooth; frontal margin straight, curving downward, not much projecting, and emarginated at the middle. Antero-lateral margin five-toothed; teeth small; angle of orbit minute, the next two teeth rounded, the last two sharp. Eyes large. Orbit with a small hiatus at the external side beneath; upper and lower margins otherwise entire. Subhepatic regions granulated. There is a thick fringe of hair on the inferior surface of the carapax around the bases of the chelopoda. Surface of hecto-gnathopoda, sternum, and abdomen pubescent. Chelopoda smooth; the right hand largest; fingers much deflexed, crossing each other at their tips. Ambulatory feet slender, slightly hairy.

Dimensions of a male: Length of carapax, 0.32; breadth, 0.495 inch.

It has some resemblance to *P. caystrus* Adams and White, but the teeth of the margin are more deeply cut than in that species.

Found at Hongkong.

87. HETEROPANOPE AUSTRALIENSIS Stimpson

PLATE VII, FIG. 7, 7a

Heteropanope australiensis STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 35 [33], 1858.

Carapax convex; proportion of length to breadth, 1 : 1.51; areolets indistinct; surface smooth but somewhat uneven anteriorly, and sparingly granulated toward the anterior margins. Antero-lateral margin with four teeth, including that behind the angle of the orbit; teeth acute, the second much larger than, but not so prominent as the third and fourth. A small tooth on the subhepatic region beneath the postorbital tooth. Front somewhat deflexed, prominently rounded and deeply emarginate at the middle; margin minutely serrated. Orbit with the hiatus of the exterior side distinct though narrow; inferior margin denticulated; tooth at inner angle prominent. Subhepatic region granulated. A fringe of hairs around and above the bases of the chelopoda. Surface of abdomen and sternum pubescent. Chelopoda stout, the right one larger; carpus somewhat regularly granulated, with a strong tooth at the inner angle; hands smooth. Ambulatory feet hairy, particularly the dactyli.

Color in life brownish above, mottled with white and bluish-black.

Dimensions of a male: Length of carapax, 0.4; breadth, 0.525 inch.

Common among muddy stones above low-water mark, on the shores of the inner harbor of Sydney (Port Jackson), Australia. It is a sluggish crab, and generally found covered with sordes.

88. HETEROPANOPE EUCRATOIDES Stimpson

PLATE VIII, FIG. 2, 2a

Heteropanope eucratoides STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 35 [33], 1858.

One specimen only, a male, of this species exists in the collection. The carapax is narrow, and resembles that of some forms of Gonoplacidæ; proportion of length to breadth, 1 : 1.25. Upper surface somewhat uneven, especially anteriorly, where there are some transverse, linear, pubescent ridges. Antero-lateral margin very much shorter than the postero-lateral, with three prominent teeth besides the little prominent anterior one, which is coalescent with the angle of the orbit. These three teeth are acute, with convex sides; the middle one is smaller than the others; the posterior one is placed at a somewhat higher level than the middle one, and projects a little

over it. The deep median emargination of the front is at the termination of a longitudinal groove on the anterior surface of the carapax, and close on each side of it the margin projects into a small rounded tooth or lobe. Margins of orbit nearly smooth, the external hiatus being nearly obsolete. Hectognathopoda smooth; their inner margins not in contact, but separated by a sufficiently conspicuous subrhomboidal space in which lie the palpi. Subhepatic and subbranchial regions smooth. Chelopoda large, resembling those of *Eucrate;* meros with a tooth near the summit; carpus smooth, with a small tooth at its inner angle; hands smooth, fingers slender, deflexed, white. Ambulatory feet slender, somewhat hairy, those of the second pair longest. Abdomen and posterior half of sternum minutely pubescent. The abdomen is narrow and tapering.

Dimensions: Length of carapax, 0.32; breadth, 0.4 inch.

The carapax in this species is narrower than in any other form of Xanthidæ. The form, the shortness of the antero-lateral margin, the form of the hands, and some other characters may perhaps indicate a genus distinct from that to which it is here referred. The general appearance is much like that of some forms of Gonoplacidæ and Carcinoplacidæ, but the position of the male verges is the same as in the Cancroids.

Found at Hongkong.

Genus PILUMNUS Leach

The numerous species referred to this genus, more than thirty of which have been now described, will probably be found upon critical examination to afford characters which will require its separation into several groups. Some of those described below are placed here with much hesitation, although agreeing with the received diagnosis of the genus.

The basal joint of the external antennæ is somewhat mobile in all the species which we have examined.

89. PILUMNUS VESPERTILIO (Fabricius) Leach

Cancer vespertilio FABRICIUS.

Pilumnus vespertilio LEACH, Trans. Lin. Soc., XI; LATREILLE, Encyc., X, 125; MILNE EDWARDS, Hist. Nat. des Crust., I, 418.

Pilumnus mus DANA, U. S. Exploring Expedition, Crust., I, 240; STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 36 [33], 1858.

This species is thickly covered with long dirty-greyish hair. The naked parts beneath are white; fingers dark brown; eyes black.

The figure given by Adams and White of their *P. ursulus* looks extremely like this species, but their description does not apply to it.

It is found on the reefs near low-water mark, generally in the crevices of the rock, to which they retreat upon the approach of the observer. It occurred to us at Loo Choo and Ousima and in Gaspar Straits.

The *P. vespertilio* of Dana seems to be a distinct species resembling somewhat *P. scabriculus* of Adams and White. The inferior margins of the hands are granulated and the body and feet are only sparsely covered with long setæ. I would propose to call it *P. danai*.

90. PILUMNUS RUFOPUNCTATUS Stimpson

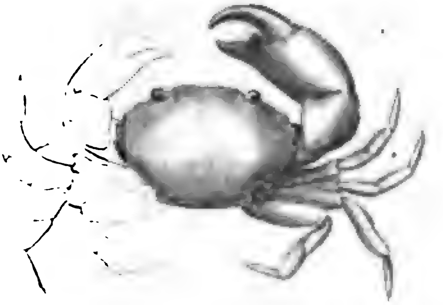
PLATE VIII, FIG. 3

Pilumnus rufopunctatus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 36 [33], 1858.

Body and chelopoda pubescent above with very short but rather stout setæ; feet hirsute. Carapax broad; proportion of length to breadth, 1 : 1.4; surface smooth posteriorly, anteriorly areolate and ornamented with about twenty blood red, subspiniform granules or small tubercles. Three of these tubercles are placed on the middle of the gastric region, close together in the median line; four, somewhat distant from each other, in an arch parallel with the superior margin of the orbit; one on each side of the group on the gastric region; and one near the lateral tooth; the remainder are scattered between these. Antero-lateral margin with three teeth, the first separated by a wide space from the angle of the orbit, in which space there is a spiniform tubercle (normally the second tooth) upon the subhepatic region, which forms the first of a series of three or four passing beneath the inferior margin of the orbit. Front rather narrow, somewhat deflected; margin denticulated and very slightly emarginated at the middle. Superior margin of orbit with three or four small, irregularly distant teeth; inferior margin six-toothed. Surface of internal suborbital lobe granulated. Chelopoda robust; carpus and hand above and externally covered with sharply projecting subdistant granules; larger hand smooth and glossy below. Sternum smooth, not pubescent.

Color brownish above, with scattered red dots (tubercles) upon the anterior part of the carapax. Larger hand yellowish below; fingers black. Dimensions of a male: Length of carapax, 0.43; breadth, 0.6 inch.

Found among muddy and weedy stones near low-water mark in Port Jackson, Australia.



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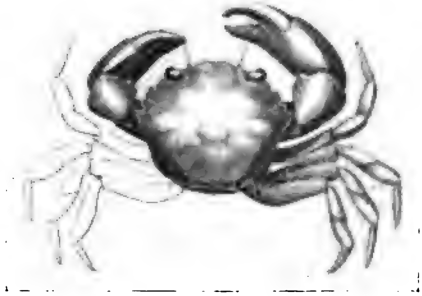

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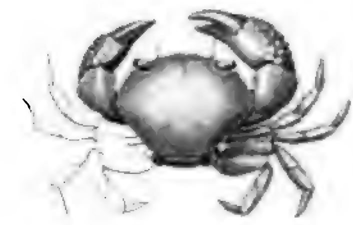

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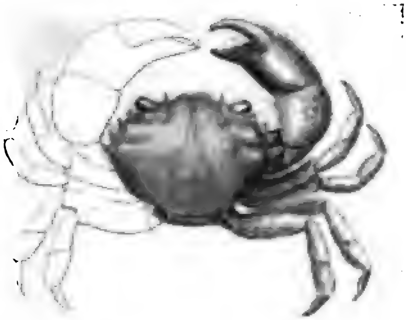

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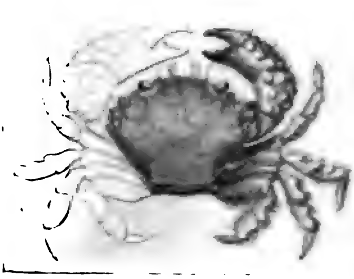

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CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

91. PILUMNUS FISSIFRONS Stimpson

PLATE VIII, FIG. 4

Pilumnus fissifrons STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 36 [33], 1858.

Body and feet covered with a thick short pubescence, which rises in transverse ridges or tufts on the anterior part of the carapax, corresponding to the areolets. Carapax convex, proportion of length to breadth in the male: 1 : 1.458; areolate toward the front and antero-lateral margins. Surface beneath the pubescence smooth and glossy. A prominent, sharp tubercle on the surface near the third antero-lateral tooth; and another, very small near the fifth or posterior tooth. Antero-lateral margin five-toothed; angle of orbit sharply prominent; a second tooth inferior, or subhepatic; posterior three teeth acute and projecting. Front rather narrow, deeply divided at the middle by an emargination or fissure; lobes much projecting, and rounded. Upper margin of orbit two-notched; lower margin minutely denticulated, with the inner angle strongly projecting and tooth-like. Hectognathopoda rather short and broad; their surface, as well as that of the neighboring regions, pubescent. Chelopoda unequal; carpus with ten or more small scattered tubercles upon its upper surface; hand sharply granulated above, the granules not crowded, and mostly concealed by the pubescence; below, smooth and glossy. Dimensions of a male: Length of carapax, 0.32; breadth, 0.465 inch.

Found at Port Jackson, Australia.

92. PILUMNUS VERRUCOSIPES Stimpson

PLATE VIII, FIG. 5

Pilumnus verrucosipes STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 36 [34], 1858.

Upper surface of body and feet minutely pubescent, with scattered long clavate setæ, most conspicuous on the margins of the feet. Carapax broad, proportion of length to breadth in the male, 1 : 1.37. Surface toward the anterior margins somewhat areolate. A strong protuberance on each side near the middle lateral tooth. Antero-lateral margin with three projecting but obtuse teeth, besides the angle of the orbit; and a protuberance on the subhepatic region, some ways beneath the interval between the angle of the orbit and the first of the three teeth. Front with a smooth and clean surface, free from pubescence; it projects a little and is slightly emarginate at the middle. Inferior margin of the orbit thick and protuberant,

particularly at the inner angle. Feet all verrucose above. In the chelopoda the carpus bears nine large verrucæ; hand with five verrucæ on its superior edge; larger hand sparsely granulous externally, smooth and glossy below; smaller hand with outer surface granulous and pubescent. In the ambulatory feet the penult and antepenult joints have each two large warts above. Dimensions of a male: Length of carapax, 0.3; breadth, 0.412 inch.

This species is a true *Pilumnus,* the basal joint of the antennæ being movable and not reaching the front, and the ridge on the palate sufficiently conspicuous.

Found among seaweeds dredged from a sandy bottom, in twelve fathoms, in Simons Bay, Cape of Good Hope.

93. PILUMNUS FORFICIGERUS Stimpson

PLATE VIII, FIG. 6, 6*a*

Pilumnus forficigerus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 36 [34], 1858.

Carapax smooth, with a velvet-like or minutely tomentose surface. Antero-lateral margin with the three posterior teeth very small; a considerable space between the anterior one and the angle of the orbit. Front broad; median lobes very little prominent and unequally rounded, being less convex externally than at their inner extremity. Postero-lateral sides concave. Surface of hectognathopoda and of the adjacent regions smooth and glossy. Chelopoda of moderate size, minutely tomentose above; carpus smooth; hand covered with irregular but strongly elevated tubercles, which are less numerous and more widely separated on the smaller hand; lower surface of hands glossy and minutely granulated. Fingers of the smaller hand with smooth, sharp, cutting edges, acting like those of shears. Ambulatory feet slender, somewhat hairy.

Colors: Carapax above red, spotted with flake-white; front very dark-red; fingers pale brown. Dimensions of a female: Length of carapax, 0.27; breadth, 0.36 inch.

Found among *Sertulariæ* and *Botrylli* dredged from a sandy bottom, in 30 fathoms, off the east coast of the island of Ousima.

94. PILUMNUS LAPILLIMANUS Stimpson

PLATE VIII, FIG. 7, 7*a*

Pilumnus lapillimanus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 36 [34], 1858.

Carapax somewhat flattened above and posteriorly; proportion of length to breadth in the male, 1 : 1.3. Surface areolate; areolets

numerous but not deeply separated, and rendered indistinct by the short pubescence which covers them. Antero-lateral margin with three small teeth, and a slight projection on the subhepatic region between the first tooth and the angle of the orbit. Superior margin of the orbit, and that of the front, denticulated. Front rather broad, nearly straight when viewed from above; median lobes broadly rounded and somewhat projecting downward. Surface of hectognathopoda smooth and glossy. Chelopoda robust; carpus above somewhat pubescent, and papillose toward its inner angle. Hands naked, their upper and outer surfaces covered with conical rose-colored papillæ, somewhat variable in size and so crowded against each other that their bases are polygonal. These papillæ give the hand a beautiful stony or crystalline appearance, its surface being more like that of a shell (*Buccinum papillosum* for instance) than that of a crab. The fingers are also minutely papillose, and slightly grooved longitudinally; both are short; the thumb triangular. The fingers of the left hand are compressed, with thin sharp, nearly smooth cutting edges as in the preceding species. Ambulatory feet tomentose and somewhat hairy above. Abdomen tomentose. Dimensions of a male: Length of carapax, 0.5; breadth, 0.65; of a female; length, 0.48; breadth, 0.65 inch.

Dredged from a shelly and sandy bottom in twenty-five fathoms in the China Sea between Formosa and the Chinese coast.

The character of the fingers of the smaller hand in the two species just described might well form the basis for the establishment of a new genus.

95. PILUMNUS HIRSUTUS Stimpson

PLATE IX, FIG. 1

Pilumnus hirsutus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 37 [34], 1858.

Body and feet hirsute above, not very thickly, with setæ of variable but moderate length. Carapax scarcely areolate, broad; proportion of length to breadth, 1 : 1.43; surface nearly smooth. Antero-lateral margin short, with four sharp teeth, including the angle of the orbit; no subhepatic tooth. Inferior margin of orbit denticulated. Eyes with rather long peduncles. Front emarginate, with a row of long setæ just above the margin. Chelopoda rather small; larger hand irregularly tuberculose above, smooth below; smaller hand (the left one) spinulose above, and sparsely granulose on the outer side; fingers pale brownish.

Color a clear light brick-red. Beneath pale red; sternum white. Fingers with brown tips. Eyes straw-colored. Dimensions of a female: Length of carapax, 0.31; breadth, 0.43 inch.

The carapax of the specimen taken at Ousima is more swollen than that of the others, and less hairy; there are a few tufts of long hairs, 4 or 6 to each tuft; two on the gastric region are most conspicuous.

De Haan's description of his *P. minutus* (Fauna Japonica, Crust., p. 50) applies very well to our species; but his figure (pl. III, fig. 2) is by no means a good representation of it. The body in that figure is smooth, the feet very slender and little hairy. The postero-lateral margin is represented as convex, while it is rather concave in our species.

Dredged in the Northern China Sea, from a shelly bottom in twenty fathoms. Also found among dead corals taken from a sandy bottom in 30 fathoms of the east coast of Ousima. A single specimen probably of this species was taken at the Bonin Islands.

96. PILUMNUS MARGINATUS Stimpson

PLATE IX, FIG. 2

Pilumnus marginatus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 37 [34], 1858.

Body and feet pilose above and below; hairs soft and flexible, entangling sordes; feet more densely covered than the carapax. Carapax transverse; proportion of length to breadth, 1 : 1.3; areolate, areolets not protuberant; surface glossy except at the roughnesses from which the hairs arise. Surface above the front covered with minute asperities. Postero-lateral surface granulated. Anterolateral and supraorbital margins raised or crested, the former with three teeth besides the angle of the orbit, the first of which is largest and less acute than the others. Median lobes of front very broad and even, not projecting. Outer and upper surface of hands, beneath the pilose covering, rugose with minute asperities and granules; carpus less rough; a small tooth at inner angle of carpus in the smaller chelopod. Dimensions of a male: Length of carapax, 0.275; breadth, 0.355 inch.

Found at Loo Choo.

97. PILUMNUS DORSIPES Stimpson

PLATE IX, FIG. 3, 3a

Pilumnus dorsipes STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 37 [35], 1858.

This globose species has almost the aspect of a *Dromia*, the short feet of the posterior pair being turned up over the back, fitting into

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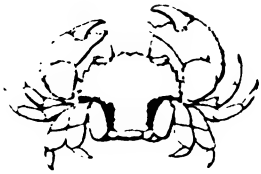

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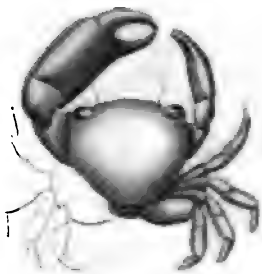

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and covering the deeply concave postero-lateral slopes of the carapax. The outline of the postero-lateral margin is so deeply concave as to form nearly a right angle at the middle. Some other species of the genus, as *P. globosus* Dana, exhibit similar characters, but none in so great a degree.

Carapax strongly convex, transverse; proportion of length to breadth, 1 : 1.32. Surface rather deeply areolate; areolets granulated and pubescent. Antero-lateral margin four-toothed (the angle of the orbit included); teeth equal, with sharp tips and denticulated margins. The furrows separating the teeth are continued inferiorly for some little distance on the subbranchial region. Median lobes of front rather prominent, equally rounded. Chelopoda large, unequal, minutely pubescent above, that on the left side smaller: hand granulated above on the outer side and on the inner inferior edge, the granules sharply projecting. Carpus with scattered granules, smallest and most crowded on a ridge around the outer base of the hand, within which there is a smooth parallel groove. Ambulatory feet rather short and broad, pubescent and hairy above, nearly smooth below. Abdomen and sternum of male pubescent.

Color of carapax obscured by the pubescence; reddish-brown, with darker spots. Dimensions of a male: Length of carapax, 0.41; breadth, 0.54 inch.

Dredged from a shelly bottom, in 10 fathoms, in the harbor of Hongkong, China.

Genus RUPPELLIA Milne Edwards

98. RUPPELLIA ANNULIPES[1] Milne Edwards

Ruppellia annulipes MILNE EDWARDS, Hist. Nat. des Crust., I, 422. DANA, U. S. Exploring Expedition, Crust., I, 246, pl. XI, fig. 4.

Our specimens agree perfectly with those of Dana. There is little doubt of their being the same as those of Milne Edwards, notwithstanding the absence of a distinct "crête horizontale" on the teeth of the antero-lateral margins. The dimensions of the single specimen in our collection, a female, are, length of carapax, 0.6; breadth, 0.94 inch.

It was taken at Great Loo Choo Island.

Genus ERIPHIA Latreille

The "red-eyes," as our seamen called the crabs of this genus, live in crevices of the rocks above low-water mark, where they seem

[1] *Lydia annulipes* (Milne Edwards).

permanently lodged. They are often secured with great difficulty, and not without injury to the specimen; for they appear in many cases to be larger than the apertures of their holes, and hence to have increased in size since taking up their residence there. It is probable, however, that, like other crabs, they come out at night to make their predatory excursions.

99. ERIPHIA LEVIMANA[1] Latreille

Eriphia levimana LATREILLE, GUÉRIN, Icon., pl. III, fig. 1. MILNE EDWARDS, Hist. Nat. des Crust., I, 427. DANA, U. S. Exploring Expedition, Crust., I, 249, pl. XIV, fig. 7.

Our specimens are specifically identical with those figured and described by Dana, and, like his, differ somewhat from Guérin's figure. Color, dark red above, bluish-white below. Eyes bright red, with white peduncles.

Found in crevices of rock, on the reefs, at and above low-water mark. It occurred at Loo Choo and at Kikaisima.

It was found by the exploring expedition at the Paumotu, Samoan, Society, and Fiji Islands.

100. ERIPHIA SMITHII[2] MacLeay

Eriphia smithii MACLEAY, Smith's Illust. Zoöl. S. Afr., Annulosa, p. 60. KRAUSS, Sudafr. Crust., p. 36, pl. II. fig. 3. DANA, U. S. Exploring Exp., Crust., I, 251.

Found in crevices of rocks, about half-tide mark, on the open coast near Hongkong, China.

101. ERIPHIA SCABRICULA Dana

Eriphia scabricula DANA, U. S. Expl. Exped., Crust., I, 247, pl. XIV, fig. 5.

Taken at Ousima.

The U. S. Exploring Expedition specimens were found at the Fiji and Society Islands and in the Sooloo Sea.

102. ERIPHIA SPINIFRONS (Herbst) Latreille

Cancer spinifrons HERBST.
Eriphia spinifrons LATREILLE; SAVIGNY; DESMAREST; MILNE EDWARDS, Hist. Nat. des Crust., I, 426; Illust. Cuv. R. A., pl. XIV, fig. 1.

A single specimen of this species was taken at Madeira; it is a female, the dimensions of the carapax of which are: Length, 0.71;

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[1] *Eriphia sebana* (Shaw).
[2] *Eriphia sebana smithii* MacLeay.

breadth, 1.01 inches. It agrees well in most characters with Mediterranean specimens, although we have had no opportunity of comparing it with an individual of the same age. The chief difference is that in our specimen the feet are thickly covered above with stout clavate setæ. The tubercles of the hands are numerous, and rather subspiniform than rounded, although blunt, and the antero-lateral teeth are sharp, spiniform, and not denticulated on their sides.

Genus TRAPEZIA Latreille

103. TRAPEZIA MACULATA[1] Dana

Trapezia maculata DANA, U. S. Exploring Expedition, Crust., I, 256, pl. xv, fig. 4.

This species seems to approach *T. cymodoce* Dana (non *Cancer cymodoce* Herbst) by imperceptible gradations.

Found on the branches of madrepores taken just below low-water mark at Hilo, Island of Hawaii.

104. TRAPEZIA RETICULATA[2] Stimpson

PLATE IX, FIG. 5

Trapezia reticulata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 37 [35], 1858.

Carapax much broader in the male than in the female. Lateral tooth small and little projecting, but acute. Front sinuous as in *T. cymodoce*. Chelopoda of moderate size, flattened; carpus obtuse; inner margin of meros convex and serrated with five or six teeth, those next the carpus little prominent. Ambulatory feet very sparsely pubescent; dactylus considerably shorter than the penult joint. This species is of a clear wine-yellow color, with a uniform rather close reticulation in fine crimson lines; below, the reticulation appears on the body but not on the feet. Eyes black. Fingers pale brown. Dimensions of a male: Length of carapax, 0.3; breadth, 0.35 inch; female, length, 0.3; breadth, 0.37 inch.

It resembles *T. areolata* Dana, but the areolæ enclosed by the colored network are much smaller and more numerous; the lateral teeth are smaller, and the teeth on the inner angle of the meros much less prominent.

Found on coral drawn up from a depth of one or two fathoms on the west coast of Loo Choo.

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[1] *Trapezia cymodoce maculata* (MacLeay).

[2] *Trapezia cymodoce areolata* Dana.

Genus TETRALIA Dana

105. TETRALIA GLABERRIMA Dana

Tetralia glaberrima DANA, U. S. Exploring Expedition, Crust., I. 263, pl. XVI, fig. 3.

Of a pale yellowish, or flesh-color. Eyes dark.

Found in crevices among madrepores taken below low-water mark in a bay on the east side of Hongkong Island; also at the Bonin Islands.

106. TETRALIA LÆVISSIMA[1] Stimpson

PLATE IX, FIG. 4, 4*a*

Tetralia lævissima STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 38 [35]. 1858.

This species is closely allied to *T. glaberrima;* but the front is scarcely denticulated; the left or larger hand is rather short and thick, glossy, pubescent as usual at the external base; fingers very widely gaping and not toothed within, their tips crossing; dactylus much curved, minutely granulated above. There is a slight tooth at the inner apex of the meros joint in the chelopoda. Dimensions: Length of carapax, 0.273; breadth, 0.298 inch.

Found at Ousima.

PORTUNIDÆ

107. PORTUNUS STRIGILIS[2] Stimpson

PLATE IX, FIG. 6

Portunus strigilis STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 38 [35]. 1858.

Body and feet everywhere pubescent, but not densely so. Carapax convex, rather narrow; proportion of length to breadth, 1 : 1.07. Surface areolate, and everywhere covered with transverse raised lines, closely arranged and somewhat undulated, smaller and more crowded posteriorly than anteriorly. Antero-lateral margin five-toothed, including the angle of the orbit; teeth of moderate size, the second and fifth generally a little smaller than the others. There is a raised line or slight crest on the postero-lateral margin, continuous with

[1] *Tetralia glaberrima* (Herbst).

[2] *Liocarcinus strigilis* (Stimpson).

the edge of the fifth lateral tooth. Interantennary front broad and projecting, laminiform, very slightly convex; margin waved, indistinctly trilobate, the median lobe smallest. Frontal region somewhat depressed and sparsely granulated. Basal joint of antennæ highly movable, its antero-interior angle scarcely meeting the front; antero-exterior angle dentiform and lying in the hiatus of the orbit. Chelopoda above and below scabrous with slight transverse ridges; hand short, costate exteriorly, and with a spine at the summit near the articulation of the dactylus. A strong sharp spine at the summit of the carpus. Meros with a slight tooth at its inferior extremity. Dactylus of the posterior or natatory feet lanceolate; the margin ciliated with long hairs.

Colors: Carapax dark purplish-brown with a large white patch in the middle; sometimes white with a purplish patch. Feet nearly white except toward their extremities. Dimensions: Length of carapax, 0.28; breadth, 0.3 inch. The specimens described are perhaps immature.

Dredged from a shelly bottom in twenty fathoms in Kagosima Bay, Southern Japan.

Genus SCYLLA De Haan

108. SCYLLA TRANQUEBARICA[1] (Fabricius) Dana

Portunus tranquebaricus FABRICIUS.
Portunus serratus RÜPPELL, Krabben des rothen Meeres, p. 19, pl. II, fig. 1.
Lupa tranquebarica MILNE EDWARDS, Hist. Nat. des Crust., I, 448.
Scylla serrata DE HAAN, Fauna Japonica, Crust., p. 44. KRAUSS, Sudafr. Crust., p. 25.
Scylla tranquebarica DANA, U. S. Expl. Exped., Crust., I, 270, pl. XVI, fig. 6.

There are two sufficiently distinct varieties of this species. That figured by Rüppell, in which the frontal teeth are sharp, is found on the shores of the continent of Asia, chiefly in muddy estuaries. It may be seen in great numbers in the markets of Hongkong and Canton. The colors in living individuals are as follows: Carapax olive green above, white below; hands often reddish, and spotted with green exteriorly, fingers always red; feet pale greenish, with darker spots below.

In Dana's variety *oceanica* the frontal teeth are blunt, with the median incision deepest; and the posterior tooth of the antero-lateral margin is longer than in the other variety. This form is found among the Pacific Islands, and was taken by us at Loo Choo.

[1] *Scylla serrata* (Forskål).

Genus LUPA Leach

109. LUPA PELAGICA[1] (Linnæus) Leach

Cancer pelagicus LINNÆUS.
Cancer reticulatus HERBST.
Cancer cedo-nulli HERBST.
Lupa pelagica LEACH, MILNE EDWARDS, Hist. Nat. des Crust., I, 450. DANA, U. S. Expl. Exped., Crust., I, 271.
Neptunus pelagicus DE HAAN, Fauna Japonica, Crust., p. 37, pls. IX, X.

A large number of specimens of this species were collected by the expedition, some of which are of great size. In the large males the carapax is maculated and streaked above with red and pale bluish; and the teeth of the antero-lateral margin have concave rather than convex sides as represented in De Haan's figures.

The females dredged near shore are not maculated, and have a convex, strongly granulated carapax.

This species was dredged on muddy bottoms in 6 to 12 fathoms in the harbors of the Chinese coast, and was found in the markets of Hongkong. It was also seen in calm weather floating or swimming in the middle of the China Sea.

110. LUPA SANGUINOLENTA[2] (Herbst) Desmarest

Cancer sanguinolenta HERBST.
Lupa sanguinolenta DESMAREST, Crust., p. 99. MILNE EDWARDS, Hist. Nat. des Crust., I, 451; Illust. Cuv. R. A., pl. x, fig. I. DANA, U. S. Expl. Exped., Crust., I, 271.
Neptunus sanguinolentus DE HAAN, Fauna Japonica, Crust., p. 38.

Carapax in living individuals sea green above, with three purplish-red spots posteriorly, the middle one largest; each spot margined with dark purplish-brown and surrounded by a ring of white. These spots are constant in size and position, affording a much better specific character than can usually be founded upon colors. The fingers of the hand are blotched with brownish within. Body beneath white.

This species was dredged on muddy bottoms in 6 to 12 fathoms in the bays near Hongkong, China. It was found most abundantly in the month of September.

[1] *Portunus pelagicus* (Linnæus).
[2] *Portunus sanguinolentus* (Linnæus).

111. LUPA SAYI[1] Gibbes

Lupa pelagica SAY (non LEACH).
Lupa sayi GIBBES, Proc. Am. Assoc., 1850, p. 178. DANA, U. S. Expl. Exped., I, 273, pl. XVI, fig. 8.

Found in the western parts of the North Atlantic Ocean, generally among gulf-weed. A fine pair, male and female, were taken together, swimming at the surface in N. lat. 33° 43′, E. lon. 67° 43′.

Genus AMPHITRITE De Haan

112. AMPHITRITE GRACILIMANUS[2] Stimpson

PLATE X, FIG. 3

Amphitrite gracilimanus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 38 [36], 1858.

Carapax convex; proportion of length to breadth in the male, 1 : 1.8. Superior surface pubescent, and transversely marked with raised, granulated lines or narrow ridges. Three of these lines cross the gastric region; the foremost interrupted at the middle; the second traversing the whole extent of the region; the posterior one shortest, and placed in the same line with the foremost ridges of the branchial region. Two short ridges on the posterior portion of the branchial region. Cardiac region somewhat prominent, with an interrupted transverse ridge, behind which its surface is granulated. Antero-lateral margin with nine sharp teeth, including the angle of the orbit; posterior tooth about twice as long as the next. Frontal margin with a median fissure, and four equal subtriangular teeth, the median ones very slightly more prominent than the lateral ones. Eyes very large, globular. Upper margin of orbit with two fissures, with an inconspicuous tooth at the outer one, which is considerably removed from the outer angle of the orbit. Inferior fissure of orbit very large. Chelopoda pubescent; elongated in the male; meros broad and thick, narrowing toward the carpus, its upper surface scabrous, with a longitudinal ridge parallel to the posterior margin; anterior margin of meros with four teeth or spines, posterior margin with two spines the outer one terminal, inner one placed far within and connected with the longitudinal ridge; carpus slender, two-spined; hand very slender with prominent longitudinal granulated ridges or costæ and three sharp spines above, two of which are

[1] *Portunus sayi* (Gibbes).
[2] *Portunus* (*Lupocycloporus*) *gracilimanus* (Stimpson).

placed near the articulation of the fingers, at a distance from them equal to one-fourth the length of the palm; fingers four-fifths as long as the palm, very slender, and compressed. Ambulatory feet slender, those of the penultimate pair very little longer than those of the posterior pair. Abdomen of male of a triangular form, though rather slender.

Color, in life, pale reddish, mottled or clouded. Dimensions of a male: Length of carapax, 0.68; breadth, 1.22; of a female: length, 0.78; breadth, 1.28 inches.

This species was dredged in considerable numbers on a muddy bottom in sixteen fathoms, off the Chinese coast near Hongkong.

113. AMPHITRITE HASTATOIDES[1] (Fabricius) De Haan

Portunus hastatoides FABRICIUS.
Amphitrite hastatoides DE HAAN, Fauna Japonica, Crust., p. 39, pl. 1, fig. 3.

This species in life is of a dark gray color above, with oblong or linear spots of black; below palish white. The lateral spines are not generally quite as long as in the specimen figured by De Haan. Our largest specimen, a female, has the following dimensions: Length of carapax, 0.875; breadth, 1.7 inches.

Found very abundantly in the harbors and bays about Hongkong Island and vicinity, on muddy bottoms, in 5 to 8 fathoms.

114. AMPHITRITE GRACILLIMA[2] Stimpson

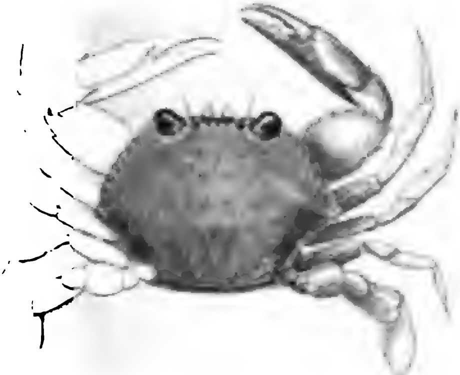
PLATE X, FIG. 2

Amphitrite gracillima STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 38 [36], 1858.

In this small species the lateral spine equals in length more than half the width of the body excluding spines. The teeth of the antero-lateral margin are minute. An acute tooth or short spine at the posterior corner of the carapax. Third pair of ambulatory feet long.

The distinctions between this and several allied species may be stated thus: From *A. longispina* and *A. vigilans* it differs in having but one spine near the base of the fingers on the upper side of the hand. From *A. tenuipes,* which it resembles in the length of the ambulatory feet, it differs in the spines at the posterior corners of the carapax. And from *A. hastatoides* it differs in its more slender

[1] *Portunus* (*Achelous*) *hastatoides* (Fabricius).
[2] *Portunus* (*Achelous*) *gracillimus* (Stimpson).



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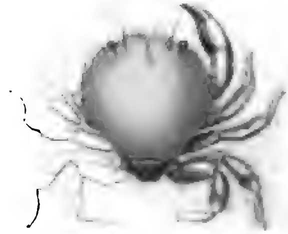

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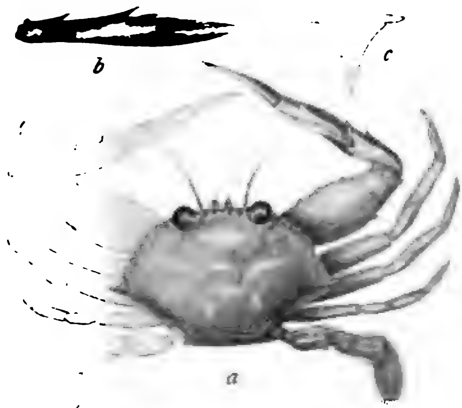

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chelopoda, longer lateral spines and ambulatory feet, by the presence of a tooth on the superior margin of the orbit, and in having the lateral teeth or lobes of the interantennal front more prominent than the median ones.

This species is of a white color, punctate with dark-brown. The only specimen taken is probably young.

Dredged on a muddy bottom in "Ten-fathom-hole" in the harbor of Port Lloyd, Bonin Islands.

115. AMPHITRITE HAANII[1] Stimpson

Amphitrite gladiator DE HAAN, Fauna Japonica, Crust., p. 39, pl. 1, fig. 5. (non *Lupa gladiator* MILNE EDWARDS).

Amphitrite haanii STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 38 [36], 1858.

The *Lupa gladiator* of Milne Edwards is described by him as "peu ou point granuleuse," and therefore can scarcely be the same as the species figured by De Haan, for which we propose a separate designation.

The general color is orange or reddish, sometimes mottled with white. The granules are often crimson. There are often bright purple spots at the articulations of the posterior pair of feet.

It was taken by us at the following localities: In the China Sea, in the parallel of 23° N., in 20 fathoms, sandy bottom; at Tanegasima, in 12 fathoms, on clean white sand; in Kagosima Bay, at the depth of 15 fathoms.

116. AMPHITRITE MEDIA[2] Stimpson

PLATE X, FIG. 1

Amphitrite media STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 39 [36], 1858.

This species is closely allied to *A. haanii* in general appearance, in the character of the front, the granulated areas of the carapax, etc., but appears constantly to differ in the smaller size of the lateral spine or posterior antero-lateral tooth, which is never more than twice as long as the next one. And the antero-lateral teeth in both of De Haan's figures are much more widely separated than in our species, in which they are close together and curved forward. The median teeth of the interantennal front are equal in size to the lateral

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[1] *Portunus (Achelous) gladiator* (Fabricius).

[2] Combined, by Alcock, with the preceding species.

ones; in this our species differs from *A. speciosa.* In the chelopoda of the female the meros joint is very broad and rather short. Dimensions of a female: Length of carapax, 0.88; breadth, 1.32 inches.

Found among floating wood in Gaspar Straits by Mr. L. M. Squires, of the steamer "John Hancock."

117. AMPHITRITE SPECIOSA[1] Dana

Amphitrite gladiator DE HAAN, Fauna Japonica, Crust., pl. XVIII, fig. 1 (?).
Amphitrite speciosa DANA, U. S. Exploring Expedition, Crust., I, 276, pl. XVII, fig. 1.

The longitudinal impressed line on the meros-joint of the chelopoda is as usual present in this species, although accidentally omitted in Dana's figure.

The color in living specimens is dark gray, mottled with white.

It was taken by us at Tanega-sima from a clean white sand bottom, in 12 fathoms; also at Loo Choo.

The specimens of Dana are from the Fijis.

Genus CHARYBDIS De Haan

118. CHARYBDIS ANISODON De Haan

PLATE XII, FIG. 1

Charybdis anisodon DE HAAN, Fauna Japonica, Crust., p. 42.

This species is easily recognized by its glabrous surface and thick two-spined hand. The color in life is palish green above, white below.

Taken by the trawl from a muddy bottom, in 6 fathoms, in a sheltered bay near Hongkong, China.

119. CHARYBDIS CRUCIFERA[2] (Fabricius) Dana

Portunus crucifer FABRICIUS, Suppl., p. 364; HERBST, Naturg. der Krabben und Krebse, pl. XXX, fig. 1.
Thalamita crucifera MILNE EDWARDS, Hist. Nat. des Crust., I, 462.
Oceanus crucifer DE HAAN, Fauna Japonica, Crust., p. 40.
Charybdis crucifera DANA, U. S. Expl. Eped., Crust., I, 286, pl. XVII, fig. 11 (?).

Color of carapax in life purplish-red, with oblong reddish-brown patches. Below pale yellowish or white. Feet above of a palish

[1] *Portunus (Achelous) granulatus* (Milne Edwards).
[2] *Charybdis cruciata* (Herbst).

dirty orange color, mottled with red. Pincers tipped with mahogany.

Very common in the vicinity of Hongkong, China, on muddy bottoms, in 6 to 20 fathoms.

120. CHARYBDIS VARIEGATA De Haan

PLATE IX, FIG. 7

Charybdis variegata DE HAAN, Fauna Japonica, Crust., p. 42, pl. I, fig. 2.

Our specimens agree very well with the species to which they are here referred, although much better with the figure than with the description of De Haan. There are some differences, however, which it is important to mention. The four median teeth of the front in our specimens are sufficiently well separated from the others; in *C. variegata* they are said not to be so separated. The hand is conspicuously rugose with transverse ridges (squamose), a character not mentioned in De Haan's diagnosis. And the antero-lateral margin is rather more convex than is represented in the figure.

The frontal teeth are not "aiguës et également espacées," as in *Thalamita callianassa* Milne Edwards (non *Cancer callianassa* Herbst).

Several specimens were dredged in the northern part of the China Sea.

121. CHARYBDIS SEXDENTATA[1] (Herbst) De Haan

Cancer sexdentatus HERBST, Naturg. der Krabben und Krebse, pl. 7, fig. 52.
Thalamita sexdentata R PPELL, Krabben des rothen Meeres, p. 4, pl. I, fig. I.
Charybdis sexdentata DE HAAN, Fauna Japonica, Crust., p. 41, pl. XII, fig. I.

Easily distinguished by its sharp frontal and antero-lateral teeth, the posterior one of which is considerably more projecting than the others. Some specimens are glossy and others pubescent. In the glossy specimens the hands are also naked and the costæ ungranulated. The color is deep green.

In our specimens the incisions separating the middle four teeth from the others are a little deeper than the other frontal notches, and the penult joint of the natatory feet is always conspicuously spinulose along the inferior edge.

Found among rocks and stones on coarse, sandy ground, at and near low-water mark, in a bay near Hongkong, China.

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[1] *Charybdis japonica* (A. Milne Edwards).

122. CHARYBDIS GRANULATA[1] De Haan

Charybdis granulata De Haan, Fauna Japonica, Crust., p. 42, pl. 1, fig. 1.

Colors in life: Pubescence of upper surface brownish; some white spots among the warts or granules, which are bright red. Below bluish, mottled with white and pale red.

Dimensions of a male: Length of carapax, 2.36; breadth, 3.4 inches.

Dredged in 10 fathoms, shelly mud, in the channels of Hongkong Harbor.

123. CHARYBDIS MILES De Haan

Charybdis miles De Haan, Fauna Japonica, Crust., p. 41, pl. XI, fig. 1.

A single specimen only was collected, a female, the dimensions of which are: Length of carapax, 1.65; breadth, 2.27 inches; proportion, 1 : 1.37. It is thus a little narrower than those measured by De Haan, in which the proportion stands 1 : 1.445.

Taken at Hongkong, China, a point at which the Portunidæ seem to reach their maximum development in size and in numbers, both of species and individuals.

124. CHARYBDIS TRUNCATA (Fabricius) Stimpson

Portunus truncatus Fabricius, Suppl., p. 365.
Thalamita truncata Milne Edwards, Hist. Nat. des Crust., I, 463. De Haan, Fauna Japonica, Crust., p. 43, pl. II, fig. 3, pl. XII, fig. 3.[2]
Charybdis truncata Stimpson, Proc. Acad. Nat. Sci. Phila., X, p. 39 [37], 1858.

This species seems to have much more affinity with *Charybdis* than with the genus *Thalamita,* to which it is referred by De Haan. Among the very numerous specimens in our collection there are none so large (two inches in breadth) as those mentioned by Milne Edwards. And the description of this latter zoölogist applies by no means as well to our specimens as do the figures and description of De Haan.

Colors in life: Carapax above dirty greenish; feet with transverse bars or patches of reddish-brown; below white.

Very common in Hongkong Harbor.

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[1] *Charybdis natator* (Herbst).

[2] In pl. XII, fig. 3, of de Haan the male is the true *truncatus* of Fabricius; the female is *C. subornata* Ortmann.

Genus THALAMITA Latreille

125. THALAMITA ADMETE (Herbst) Milne Edwards

Cancer admete HERBST.
Thalamita admete MILNE EDWARDS, Hist. Nat. des Crust., I, 459; Illust. Cuv. R. A., pl IX, fig. 2. DANA, U. S. Expl. Exped., Crust., I, 281, pl. XVII, fig. 5.

Found at the Island of Ousima. A young specimen, probably of this species, occurred in 5 fathoms, black sand, in Kagosima Bay.

126. THALAMITA INTEGRA Dana

Thalamita integra DANA, U. S. Exploring Expedition, Crust., I, 282, pl. XVII, fig. 6.

Color in life: Glaucous with white dots, as if sprinkled with sand; below white; pincers dark brown, tipped with white.

Taken on a sandy bottom, in six fathoms, in Katonaisima Straits, Ousima. Young specimens, probably of this species, occurred at Kikaisima and at the Bonin Islands. Dana found it at the Paumotu and Hawaiian Islands.

127. THALAMITA SIMA Milne Edwards (?)

PLATE XI, FIG. 2

Thalamita sima MILNE EDWARDS, Hist. Nat. des Crust., I, 460.

The description of *T. sima* given by Milne Edwards is very short, and it is by no means certain that the species here referred to is the same.

The following description is taken from a large male, one of the very numerous specimens collected by the expedition at Hongkong. The proportion of length to breadth in the carapax is 1 : 1.65. Upper surface moderately convex at the middle and posteriorly, pubescent and marked with several transverse granulated lines. Interorbital front equaling half the width of the carapax and simply emarginated as in *T. admete,* but advanced a little at the median notch. Antero-lateral margin more or less oblique and armed with five sharp teeth, including the angle of the orbit; the fifth or posterior tooth larger; the fourth a little smaller than the rest. Hectognathopoda and pterygostomian regions pubescent. Chelopoda large, strongly spinose and squamose; the subsquamiform transverse ridges, with granulated and pubescent margins, are shorter and more irregular above

than below; on the lower surface they are most regular and nearly continuous, being interrupted only at the median groove. Anterior margin of meros-joint with two strong curved teeth near the dentiform outer angle, and six or eight small tuberculiform teeth toward the base; four small tubercles on the surface above and between the large teeth. No teeth on the outer side of the meros, which is only squamose. Carpus strongly squamose and pubescent; a strong spine at the summit and three small ones on the outer surface. Hand with five spines above and two or three costæ on the outer surface; fingers strongly grooved, the ridges between the grooves smooth and glossy. Ambulatory feet pubescent; penult and antepenult joints grooved; penult joint of natatory feet with no spines on its posterior margin, terminal joint with the sharp tip projecting considerably beyond the margin.

Colors in life: Above, obscured by the pubescence, blackish and whitish mottled; below, bluish; mouth and parts adjacent, reddish; pincers with black blotch at the middle, tips white. Dimensions of the male: Length of carapax, 1.5; breadth, 2.48 inches.

De Haan's *T. arcuatus* is perhaps the young of our species, but the hands are described as smooth below.

Found abundantly in sheltered bays near Hongkong, China, on muddy bottoms, in 4 to 6 fathoms; it also occurred in Gaspar Straits and at Simoda, Japan.

128. THALAMITA CRENATA Rüppell

PLATE X, FIG. 6, 6a

Thalamita crenata RÜPPELL, Krabben des rothen Meeres, p. 6, pl. v. fig. 2. MILNE EDWARDS, Hist. Nat. des Crust., I, 461 (?).

Carapax glossy, free from pubescence except toward the margins. Crest of basal joint of antennæ not projecting beyond the frontal margin. Outer surface of hand smooth. In some of our specimens, as in those of Rüppell, there are a few spines on the posterior border of the penult joint of the natatory feet. Color in life dark green above, paler below; pincers dark red, with yellowish teeth.

Taken in a seine from a small muddy creek in Napa Harbor, Loo Choo, where it seems to be abundant; also found at Hongkong.

There are evidently two species confounded under the name *T. crenata*, and we are somewhat in doubt as to which species the name should be applied. Rüppell's figure certainly represents the smoother species, rather than that called *T. crenata* by Dana, which latter, however, may not improbably be the *T. crenata* of Milne Edwards.

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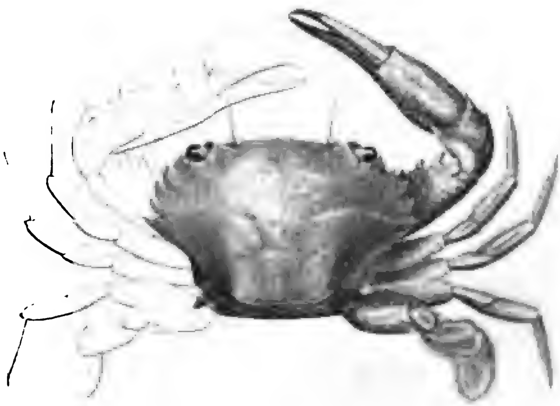

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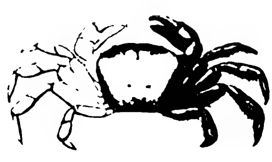

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who compares it with *T. admete,* to which species Dana's crab approximates much more closely than that of Rüppell.

The German naturalist seems to have priority in the use of the term *crenata,* for, although he refers to Latreille for the name, we can nowhere find a description by the latter author.

129. THALAMITA DANÆ Stimpson

PLATE XI, FIG. 1, 1a

Thalamita crenata DANA, U. S. Exploring Expedition, Crust., I, 282, pl. XVII, fig. 7.

Thalamita danæ STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 39 [37], 1858.

Easily distinguished from *T. crenata* by the granulous and costate outer surface of the hand and the more deeply cut teeth of the front. It approaches more closely *T. crassimana* Dana (*prymna* De Haan). The crest of the basal joint of the antennæ projects beyond the frontal margin.

Color in life dark purplish-red or brick-red above, much lighter below.

Found under stones on coarse sandy ground, above low-water mark, in the harbor of Hongkong, China.

130. THALAMITA PICTA Stimpson

PLATE X, FIG. 5

Thalamita picta STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 39 [37], 1858.

This is a small, prettily-colored species, of which two specimens only were obtained. The proportion of length to breadth in the carapax of the male is 1 : 1.58. Upper surface pubescent and marked with transverse raised lines arranged as in *T. danæ,* the lateral lobes of the anterior set of lines on the gastric region being behind the median ones, and not in the same range as in *T. crassimana.* Antero-lateral margin a little oblique, five-toothed, including the angle of the orbit, the fourth tooth much smaller than the fifth, which nearly equals the third in size. Frontal margin a little prominent at the middle and deeply crenated, with six lobes (excluding the præorbital teeth), the median two lobes small and rounded, the next ones broad, the external ones small and pointed. Basal joint of external antennæ with a short, sharply compressed, smooth-edged laminiform crest, the middle portion of which projects beyond the front. Chelopoda squamose and pubescent above; spines nearly as in *T. danæ;* spine at inner angle of carpus very long; hand costate

externally. Inferior edge of penult joint of natatory feet with seven distinct, rather large spinules.

Color in life grayish and yellowish mottled. An oblong crimson patch on the anterior part of the carapax extending between the eyes and a smaller crimson patch posteriorly. Pincers with two or three dark-brown annulations; tips white. Dimensions of a male: Length of carapax, 0.47; breadth, 0.745 inch.

Found among boulders and stones above low-water mark in Foukow Bay, Island of Ousima.

131. THALAMITA CRASSIMANA[1] Dana

Thalamita prymna DE HAAN, Fauna Japonica, Crust., p. 43, pl. XII, fig. 2 (non HERBST et MILNE EDWARDS).
Thalamita crassimana DANA, U. S. Exploring Expedition, Crust., I, 284, pl. XVII, fig. 9.

Found at Loo Choo, in muddy bays, just below low-water mark.

Genus ANISOPUS De Haan

We may retain the name *Anisopus* for those species of *Platyonichus* in which the median tooth of the front is bifid and the teeth of the antero-lateral margin approximated.

132. ANISOPUS PUNCTATUS[2] De Haan

Anisopus punctatus DE HAAN, Fauna Japonica, Crust., p. 44, pl. II, fig. 1.

Color in life reddish, from clouds of reddish-brown punctæ. Carapax with a clear blue spot at each posterior corner; also a W-shaped blue spot, with a dark-red patch in front of it, at the middle.

It is taken with seines on the sandy shores of Hakodadi Bay, Island of Jesso, and is used as food by the inhabitants. It was also obtained from the fishermen off the northeast coast of Niphon, where it seems to be very common.

[1] *Thalamita prymna* (Herbst).
[2] *Ovalipes bipustulatus* (Milne Edwards).

CORYSTOIDEA

Genus TRICHOCERA De Haan

133. TRICHOCERA GIBBOSULA[1] De Haan

Trichocera gibbosula DE HAAN, Fauna Japonica, Crust., p. 45, pl. II, fig. 4, pl. XIII, fig. 3.

Our single specimen is small, about one-third of an inch in length. The rostrum is more projecting and the protuberances of the dorsal surface of the carapax much sharper than is represented in De Haan's figures. There is little doubt, however, that it is only the young of the species above cited.

Dredged from a sandy bottom, in 30 fathoms, off the northeast coast of Niphon.

Genus KRAUSSIA Dana

134. KRAUSSIA NITIDA Stimpson

PLATE X, FIG. 4

Kraussia nitida STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 40 [37], 1858.

Carapax suborbicular; proportion of length to breadth, 1 : 1.12. Upper surface glossy and nearly smooth; obsoletely crenulate-lineolate. Interantennal front much projecting, divided into two lobes by a deep median emargination or fissure; each lobe is also nearly divided in two by an excavation of less depth. Margins of front ciliated. Superior margin of orbit with a deep fissure near the inner side. There are five short longitudinal impressed lines on the anterior part of the carapax, terminating in the fissures of the front and orbits. Antero-lateral margin ciliated, smooth in appearance, but minutely crenulated, and with three or four inconspicuous emarginations indicating the normal teeth. Postero-lateral margin very short and concave. Chelopoda nearly smooth; hand above obsoletely lineolated; dactylus with longitudinal ridges above, somewhat crenulated near the base; a minute spine on the front of the carpus and one near the summit of the meros-joint. Posterior feet with long hairs on their margins.

Color in life white; carapax sometimes cream-colored, and often streaked with flesh color. Pincers brown. Dimensions of a male: Length of carapax, 0.32; breadth, 0.36 inch.

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[1] *Cancer gibbosulus* (De Haan).

It differs from *K. integer* Dana (*Xantho integer* De Haan) in its narrower carapax and more projecting front; from *K. rugulosa* and *K. porcellana* in the want of spines on the antero-lateral margin.

Dredged in 20 fathoms, black sand, in Kagosima Bay, Japan; also in the northern China Sea, latitude 23°, from 24 fathoms, shelly sand.

Genus CHEIROGONUS Latreille

135. CHEIROGONUS ACUTIDENS[1] Stimpson

PLATE XII, FIG. 3

Cheirogonus acutidens STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 40 [37], 1858.

Carapax rather narrow; proportion of length to distance between tips of lateral teeth, 1 : 1.26. Surface covered with setiferous tubercles, mostly transverse, as in other species of the genus. Lateral tooth slender, sharp, the principal or middle one very long, a small intermediate tooth at the base of the principal one behind. Between the teeth and sometimes on their edges there are a few small spiniform denticles. Interantennal front or rostrum with a deep median sinus and a smaller sinus or excavation at the tip of each fork, as in *C. hippocarcinoides.* Antennæ more than one-third as long as the carapax. Feet all squamose or scabrous and setose. Chelopoda somewhat spinous above; hand costate externally, the costæ sharply tuberculated.

Color in life light brick-red above; paler, inclining to yellowish, below. Some specimens are of an orange color, but always dusky. Pincers dark brown. Dimensions of a male: Length of carapax, 1.45; breadth between tips of lateral teeth, 1.83 inches. It grows to a length of three inches, but the larger specimens, of which several were collected, were accidentally lost.

It may be distinguished from *C. hippocarcinoides* as found on the west coast of America, as well as from *Telmessus serratus* White, by the greater length and acuteness of the lateral teeth, particularly the larger one; also by the existence of a small intermediate tooth behind the large one.

This crab is very common in the Bay of Hakodadi, in northern Japan. It is commonly taken with the seine on sandy shores, but often occurs on gravelly beaches above low-water mark. In June the young, of half an inch to an inch in length, were much more

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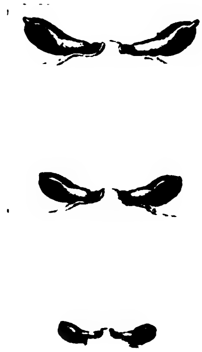
[1] *Telmessus acutidens* (Stimpson).

1



2

3

CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

abundant than adults, and were taken with the dredge in 4 fathoms, weedy sand.

In the time of Steller a species of *Cheirogonus* was so abundant in Avatcha Bay (Kamchatka) that it formed a common article of food among the inhabitants. At the present time, however, it has entirely or nearly disappeared, as we did not succeed in obtaining a specimen; nor do the naturalists of Beechey's voyage mention having found it.

Genus NAUTILOCORYSTES Milne Edwards

The name *Dicera*, proposed for this genus by De Haan and retained by Krauss and Dana, was published before that of Milne Edwards. The name given by the latter naturalist is, however, retained, as *Dicera* was several times preoccupied as a generic term in zoölogy, and once among the Articulates.

136. NAUTILOCORYSTES OCELLATUS[1] Milne Edwards

Dicera octodentata DE HAAN, Fauna Japonica, Crust., p. 15 (no descr.). KRAUSS, Sudafr. Crust., p. 27.
Nautilocorystes ocellatus MILNE EDWARDS, Hist. Nat. des Crust., II, 149.

Dredged on a sandy bottom, in 12 fathoms, in Simons Bay, Cape of Good Hope.

OCYPODOIDEA

CARCINOPLACIDÆ

Genus PILUMNOPLAX Stimpson

This genus was instituted for a group of small Carcinoplacidæ having much the aspect of *Pilumnus* in their shape and frequent setose covering, but easily distinguished by the depressed form and great posterior breadth of the carapax as well as by the character of the male organs. The antero-lateral margin is very short; the eyes and orbits very small and rounded. The facial and oral members are nearly as in *Pilumnus*. The basal joint of the antennæ is movable, and does not reach the frontal margin. The meros-joint of the external maxillipeds is nearly square. The palate is on each side divided by a ridge more or less distinct. The chelipeds are generally short. The ambulatory feet are long and slender, those of the penultimate pair usually the longest; the dactyli flattened, and in the

[1] *Nautilocorystes octodentatus* (De Haan).

are two smooth, oblong longitudinal ones on the anterior part of the gastric region just behind the front. These, as well as two near the anterior corners of the carapax, are very prominent. Lateral margin anteriorly with five tuberculiform or paxilliform teeth, the posterior two smooth, the two next anteriorly prominent and setose, the anterior one small, forming the angle of the orbit. Front deflexed, with a supramarginal fringe of long hairs; margin curved and notched at the middle. Eye peduncles setose. The grooves separating the posterior teeth of the lateral margin are continued for a considerable distance upon the sub-branchial region, passing obliquely forward. Chelipeds with the meros and carpus deeply sculptured with setose grooves, dividing the upper side of each joint into five or six prominent, smooth, wart-like protuberances. A small, sharp tooth at the inner angle of the carpus. Outer surface of hand with a setose coating, beneath which there are minute sharp granules showing a tendency to arrangement in longitudinal rows. Ambulatory feet longitudinally grooved. Dimensions: Length of carapax, 0.22; breadth, 0.28 inch.

This species occurred at Ousima.

140. PILUMNOPLAX CILIATA Stimpson

Pilumnoplax ciliata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 94 [40], 1858.

Description of a female: Anterior margins of body and feet densely ciliated with long hair-like setæ. Carapax broad, somewhat narrowed and flattened posteriorly. Proportion of length to breadth, 1 : 1.58. Upper surface even and nearly smooth, pubescent, a few granules distantly scattered toward the margins. Seven short longitudinal sulci on the frontal and supraorbital regions, the median one arising from the frontal emargination. Front broad, with a supramarginal series of long setæ continuous with those on the orbital and antero-lateral margins. Orbit with two deep fissures at the outer side, one above and one below the exterior angle; a slight fissure also on the superior margin. Antero-lateral margin with three deep notches dividing four teeth, the anterior one being confounded with the angle of the orbit; teeth all broadly truncated with the exception of the posterior one, which is small and sharp. Subhepatic region behind the orbit eroded or rugose. Basal joint of antennæ rather short. Chelipeds short, equal; meros with a thin, sharp, irregularly dentated superior crest; carpus hairy, with the inner angle acute; hand sharply granulated and setose, with the exception of its inner

surface and a space externally at the base of the fingers, which appears as if worn smooth; setæ of superior margin very long; fingers somewhat deflexed, rounded, a little gaping, deeply sulcated within, externally partly granulated. Ambulatory feet compressed, those of the penult pair longest; superior margins of last three joints ciliated; meros-joint with a smooth, sharp, thin superior crest. Dactylus of posterior pair short, little more than half as long as that of penult pair, and somewhat curved. Dimensions of carapax: Length, 0.38; breadth, 0.6 inch.

Of this curious species a single specimen only was obtained. It is much broader than other species of the genus, and were it not for its deeply toothed and ciliated antero-lateral margin and its short chelipeds might well be referred to *Carcinoplax*.

It was found in the port of Simoda, Japan.

141. CARCINOPLAX EBURNEA Stimpson

Carcinoplax eburneus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 94 [40], 1858.

This is a very small species, of which, however, a sufficient number of examples were taken to illustrate it fully. The carapax is very broad, with a hard, smooth, ivory-like surface. Proportion of length to breadth, 1 : 1.75. Sides evenly rounded, tumid, with a slightly raised horizontal marginal line or crest, the antero-lateral portion of which is armed with two or three very minute, inconspicuous teeth. Front broad, straight, slightly pointed at the middle. Orbits small, rounded, margins entire. Subhepatic regions swollen. Palate divided by a ridge on either side. Buccal area short, very broad in front and narrowed behind. External maxillipeds nearly as in *C. longimana*, except that the exognath is broader, with a spiniform tooth, and the outer margin of the endognath is deeply concave; the meros is much broader than the ischium and much produced at its external apex or auricle; finally the palpus is rather endarthroid than goniarthroid. Chelipeds long and slender, with glossy surface; meros slightly hairy on the edges; carpus small; hand elongated with a smoothly-rounded and somewhat swollen palm; fingers slender, as long as the palm, sharply dentated within, teeth small, tips hooked, crossing each other. Ambulatory feet slender, with hairy edges. Abdomen of the male triangular, median segments soldered, margin toothed at base. Abdomen of the female triangular.

The color in life is pale brownish or yellowish; three diverging white streaks on the posterior part of the carapax; chelipeds darker;

beneath white. Dimensions of the carapax in a male: Length, 0.16; breadth, 0.28 inch.

It was dredged from a muddy bottom, in the "ten-fathom hole," at Port Lloyd. Bonin Islands.

Genus HETEROPLAX Stimpson

This genus is allied to *Carcinoplax* in the character of the male organs, and to *Gonoplax* in the shape of the carapax and the form of the orbits. The carapax is trapezoidal, the facial region occupying nearly its whole width anteriorly. Front rather broad, notched on either side at the insertion of the antennæ. Eye-peduncles stout and of moderate length. Antennæ long and slender, the basal joint movable, narrow, elongated, its outer apex filling the hiatus of the orbit and nearly excluding the flagellum therefrom. Epistome ample. Palatal ridge sufficiently distinct at the anterior buccal margin. External maxillipeds resembling those of *Gonoplax*, with goniarthroid palpus. Chelipeds short, robust; fingers oblique. Ambulatory feet slender, the third pair longest; dactylus compressed. Abdomen of the male very narrow, but expanded at base so as to cover the posterior segment of the sternum and reach the coxæ of the posterior feet. The virgulæ, or male organs, arise from these coxal joints, but reach the abdominal appendages through shallow grooves on the sternum.

The species are found on the coast of China.

142. HETEROPLAX DENTATA Stimpson

Heteroplax dentata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 94 [40], 1858.

Carapax narrow, a little broader at the principal lateral tooth than at the angle of the orbit. Proportion of length to breadth, 1 : 1.27. Surface smooth and glossy; regions inconspicuous. Hepatic region depressed. Antero-lateral and postero-lateral margins nearly continuous, the former very short, with four unequal teeth, the third tooth much the largest and most prominent, placed at a higher level than the second and projecting over it; fourth or posterior tooth inconspicuous, formed only by a slight emargination. Front straight, somewhat bimarginate; no median notch. Eyes large. Chelipeds short, smooth, and glossy; a small tooth near the summit of the meros-joint and one at the inner angle of the carpus, and a tuft of pubescence on the outer surface at the juncture of the carpus and hand.

The colors in life are as follows: Carapax gray or brown, whitish posteriorly, and with a transverse narrow white band behind the eyes. The frontal region and feet punctate with red. The species presents little or no variation in color. Dimensions of the carapax in a male: Length, 0.3; breadth, 0.383 inch.

Found in considerable numbers on shelly bottoms, in 10 and 15 fathoms, among the islands on the coast of China near Hongkong.

143. HETEROPLAX TRANSVERSA Stimpson

Heteroplax transversa STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 94 [40], 1858.

This species is allied to *H. dentata,* but may be distinguished by its much broader carapax, the proportion of length to breadth in which is 1 : 1.46. The principal lateral tooth is smaller but acute; the tooth forming the angle of the orbit is more prominent, and the second tooth almost obsolete. The ocular peduncles are longer. Colors as in the preceding species. Dimensions of carapax in a male: Length, 0.26; breadth, 0.38 inch.

Taken in the harbor of Hongkong.[1]

MACROPHTHALMIDÆ

Genus MACROPHTHALMUS Latreille

149. MACROPHTHALMUS TELESCOPICUS (Owen) Dana

Gelasimus telescopicus OWEN, Voy. Beechey, Zoöl., 78, pl. XXIV, fig. 1.
Macrophthalmus compressipes RANDALL, Jour. Acad. Nat. Sci. Phila., VIII, 123.
Macrophthalmus podophthalmus EYDOUX and SOULEYET, Voy. Bonite, Crust., pl. III, fig. 67. MILNE EDWARDS, Mél. Carcin., 119.
Macrophthalmus telescopicus DANA, U. S. Exploring Expedition, Crust., I, 314.

The color of the (young) specimens taken by us was pale grayish with whitish mottlings; darker anteriorly. They were dredged from a depth of 10 fathoms on a sandy mud bottom in the harbor of Napa, Loo Choo.

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[1] The family Rhizopidæ, comprising two pages of Stimpson's "Prodromus" and Nos. 144 to 148, inclusive, of the species, is missing from the manuscript of this report; also the illustrations of this family, as well as of other Ocypodoidea. This gap existed in 1875, when the manuscript was examined by Prof. Sidney I. Smith, and it is probable that the missing parts were removed by Dr. Stimpson himself for further study and were destroyed in the Chicago fire in 1871.

150. MACROPHTHALMUS SERRATUS White

PLATE XIII, FIG. 3

Macrophthalmus serratus WHITE, Voy. Samarang, Crust., p. 51.

Our species agrees pretty well with White's description of his *M. serratus,* but as no figure of that species is given and as the description itself is short and unsatisfactory we do not consider the identification as certain.

In our specimens the carapax is broader posteriorly than at the angles of the orbits. Proportion of length to breadth, 1 : 1.4. Surface granulose, with the exception of a smooth space at the middle of the gastric region. Lateral margin quadridentate, the small fourth or posterior tooth being only the anterior extremity of a slight crest which margins the posterior third of the side. Ambulatory feet not pectinated, but villous, the hair short and soft. It differs from *M. simplicipes* in the want of tubercles on the carapax, and from *M. affinis* in being narrower anteriorly and having a more strongly dentate margin. Living specimens were brownish or dust-colored above, white below. The dimensions of a male are: Length of carapax, 0.85; breadth, 1.19 inches.

A small *Lepas* is found in considerable numbers upon the feet of this species.

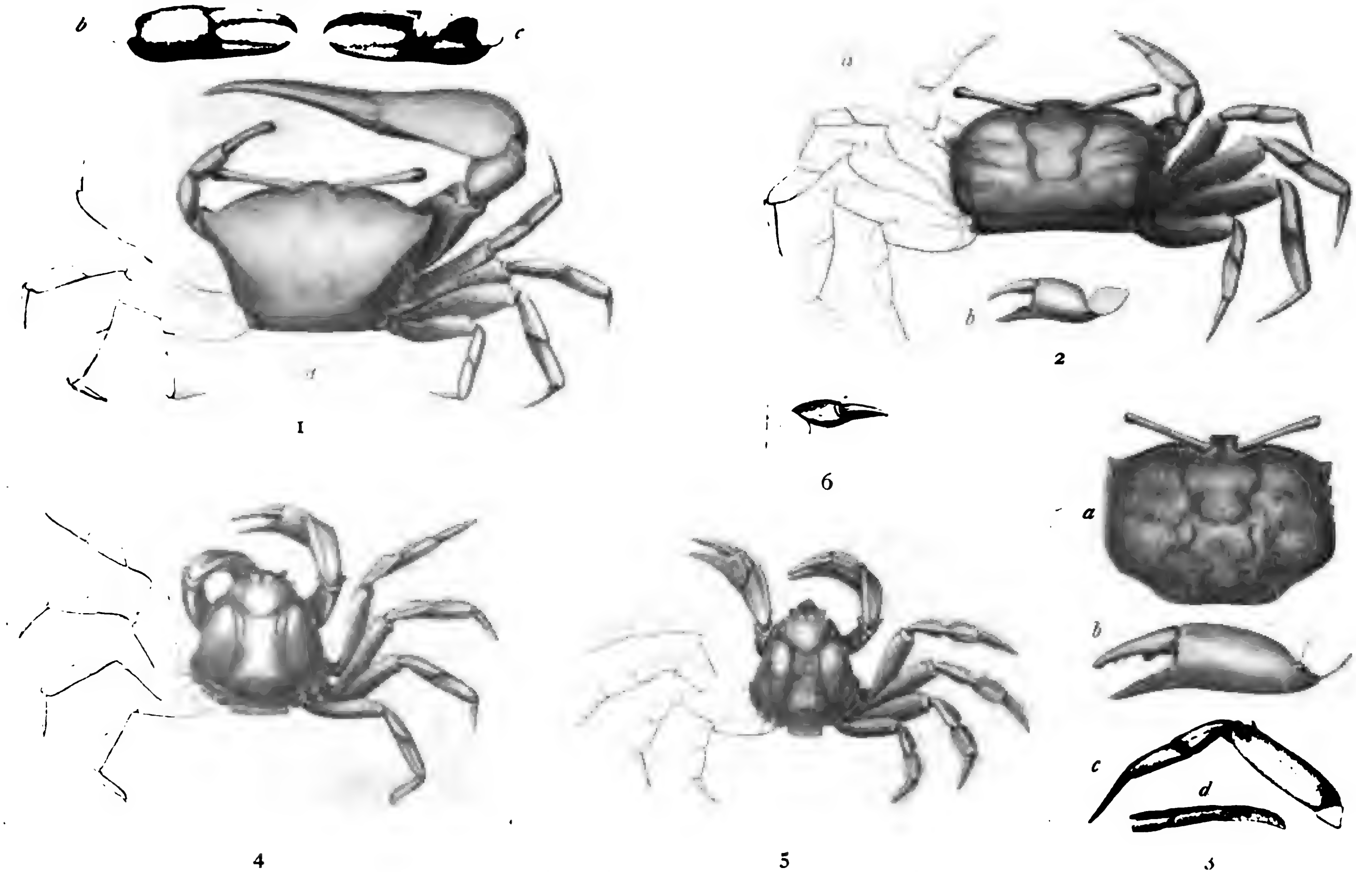
It was dredged in abundance on muddy bottoms, in 4 to 10 fathoms, in and near the harbor of Hongkong.

151. MACROPHTHALMUS DENTATUS Stimpson

PLATE XIII, FIG. 1

Macrophthalmus dentatus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 97 [43], 1858.

Carapax broad, length to breadth as 1 : 1.67. Upper surface naked, uneven, but smooth and glossy, except toward the postero-lateral angle, where there are two slightly raised, plicated longitudinal ridges. Lateral margin armed with teeth nearly throughout its length; teeth four in number, small, except the anterior one, which forms the angle of the orbit and is long and acute. Front very narrow. Eyes long, but falling short of the extremity of the orbital angle. Chelipeds angular, but everywhere smooth and glossy; fingers short; immovable finger very short, armed within by a large triangular tooth at the middle, which bears a denticle on its anterior side; dactylus with a tooth at the base and another small but well-separated one near the



CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

base. Ambulatory feet smooth, scarcely at all hairy; meros with a small spine near its superior extremity.

The color in life is bluish-gray with darker mottlings; below white. Dimensions of the carapax in a male: Length, 0.31; breadth between tips of orbital angles or teeth, 0.52 inch.

This crab, like some of its congeners, feigns death when caught, remaining perfectly quiescent, with its feet outstretched, as if in asphyxia.

It is found on mud bottoms, in 6 fathoms, in the bays near Hongkong.

152. MACROPHTHALMUS CONVEXUS Stimpson

PLATE XIII, FIG. 2

Macrophthalmus convexus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 97 [43], 1858.

Carapax broadest at the external angles of the orbits, convex, especially posteriorly; length to breadth as 1 : 1.74. Surface smooth and glossy, except toward the lateral margins, where it is somewhat granulose. Regions distinct. Two granulous protuberances in a longitudinal line on the branchial region near the postero-lateral corners of the carapax. Sides crested, with two emarginations anteriorly, the posterior one inconspicuous. Tooth forming the angle of the orbit sharply prominent. Orbits somewhat oblique; inferior margin serrated. Hands and fingers pilose within. The fingers each bear a tooth on the inner margin near the base, as in *M. pacificus*. Ambulatory feet smooth; tooth near summit of meros very small. Male organs long and slender.

Dimensions of the male specimen, which is perhaps immature: Length of carapax, 0.34; breadth, 0.59 inch.

Found at Loo Choo.

153. MACROPHTHALMUS PACIFICUS Dana

Macrophthalmus pacificus DANA, U. S. Exploring Expedition, Crust., I, 314, pl. XIX, fig. 4.

Found at Loo Choo.

Genus CHÆNOSTOMA Stimpson

The chief character of the genus *Cleistostoma,* as understood by Dana, is found in the large relative size of the meros-joint of the external maxillipeds, which nearly equals the ischium in length. In

his *C. boscii* (vix *Macrophthalmus boscii* Auct.) this character is apparent, but the maxillipeds are widely gaping, while in De Haan's *Cleistostoma* they fit close to each other along the inner edges—a character from which the name of the genus was derived. In Milne Edwards's *Euplax*, which would include, according to the French naturalist, the true *M. boscii*, the maxillipeds are said to resemble those of *Macrophthalmus*, where the meros is much smaller than the ischium. So that Dana's species will not strictly belong to either genus, and we have ventured to arrange it, with one other before undescribed, under a new generic name.

The carapax resembles that of *Euplax*, but the eyes and their peduncles are considerably larger and thicker than in that genus.

154. CHÆNOSTOMA ORIENTALE[1] Stimpson

Cleistostoma boscii DANA, U. S. Expl. Exped., Crust., I, 313, pl. XIX, fig. 3.
Chænostoma orientale STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 97 [43], 1858.

This species differs from the *Macrophthalmus boscii* of Savigny in the larger meros-joint of the external maxillipeds. The oblique concavity on the surface of this joint is also deeper.

It was found by us among the Loo Choo Islands.

155. CHÆNOSTOMA CRASSIMANUS[2] Stimpson

Chænostoma crassimanus STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 97 [43], 1858.

The following is a description of a male: Carapax quadrilateral, areolated, more convex posteriorly than anteriorly. Length to breadth as 1 : 1.31. A deep and narrow longitudinal furrow on the pregastric region, bifurcating posteriorly. Surface uneven, rough and hairy toward the lateral margins, but smooth and glossy near the middle. Lateral margin not denticulated; there is, however, a slight emargination behind the tooth forming the angle of the orbit. The eyes are large, with thick peduncles, and reach slightly beyond the extremity of the orbit. The front is broad, deflexed, and broadly subtruncate below. Infraorbital margin minutely crenulated. The anterior margin of the buccal area is deeply sinuous, the angles being filled up by a protruding lobe, leaving a broad and deep sinus in the middle, the margin of which is straight and salient; this sinus is

[1] *Euplax boscii* (Audouin).
[2] *Euplax crassimanus* (Stimpson).

filled by the palpi of the outer maxillipeds. There is no piliferous crest on the outer maxillipeds, which are rather broad and gaping, so as to leave a rhomboidal space between; the meros-joint is but little longer than broad. Chelipeds robust, smooth externally, hairy within; hand very thick, and about three-fourths as broad as long, with glossy outer surface; fingers short, acute; dactylus armed with a strong tooth at the middle of the inner edge; immovable finger minutely crenulated on the inner edge. Ambulatory feet compressed, slightly canaliculated above, nearly smooth; meros-joint very hairy, the other joints almost naked. Abdomen sufficiently broad, oblong, not much tapering, seven-jointed; third joint swollen on each side of the median line. Dimensions of carapax: Length, 0.26; breadth, 0.341 inch.

The above description includes some generic characters, but is given in full for the better illustration of the genus.

A single specimen was taken at Loo Choo.

156. METAPLAX LONGIPES Stimpson

Metaplax longipes STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 97 [43], 1858.

One specimen only, a male, of this species was collected, of which the following is a description. Carapax small in proportion to the length and size of the limbs. Proportion of length to breadth, 1 : 1.33. The greatest breadth is across the middle. Surface somewhat uneven, but glossy and punctate about the middle and anterior portions. There are two conspicuous areolets on each side, marked off by transverse depressions arising from the lateral fissures. On the postero-lateral slope the surface is pubescent and marked with two striæ or raised lines proceeding from marginal fissures; the anterior stria transverse, the posterior one oblique. Front very broad. Frontal region deeply and broadly excavated longitudinally along the middle. Lateral margin three-notched, the first or anterior notch very deep, separating a strong tooth, which is somewhat turned up; the other notches very slight. Eyes stout, of moderate length. Infraorbital margin seven-lobed, lobes rounded, smooth, glossy, decreasing in size outwardly, the innermost lobe being the largest and most projecting, somewhat curving downward. Epistome ample, convex. Antero-inferior regions granulated and sulcated near the mouth, pubescent near the lateral margins. Beneath the infraorbital margin the sulcus is very deep, and under the internal lobe of this margin there is a deep cavity. External maxillipeds rhomboidally gaping, profoundly sulcated, making the inner oblique piliferous crest very

prominent. Chelipeds moderately elongated; meros serrulated along the angles; hand smooth, oblong, a little inflated within; fingers gaping, evenly denticulated within; tips excavated internally, with sharp corneous outer edges for nipping or cutting. Ambulatory feet long, smooth, pubescent at base, the first and last pairs reaching only to the penult joints of the middle pairs, which joints are everywhere thickly pubescent; dactyli somewhat compressed, five-sided or quinquecostate, tapering to slender sharp extremities. Abdomen with all the segments distinct; terminal joint abruptly smaller than the penult. The margin of the sternum is raised into a crest around the terminal abdominal segment. Dimensions of the carapax: Length, 0.46; breadth, 0.61 inch. Length of ambulatory feet of the second pair, 1.38 inches.

This species differs from *M. distinctus* in the lobation of the infra-orbital margin, and from *M. indicus* in its narrower carapax and the distinct segmentation of the abdomen.

Found in Hongkong Harbor.

Genus ILYOPLAX Stimpson

Body tetragonal, very thick. Carapax very little indurated. Front, antennæ, antennulæ, and orbits nearly as in *Macrophthalmus;* the front is, however, broader than in that genus. Eye-peduncles sufficiently long. External maxillipeds saillant, not gaping; exognath concealed, palpigerous; meros of endognath large, longer than broad, and longer than the ischium; ischium ornamented with an oblique, almost transverse piliferous line placed close to the commissure of the meros; palpus rather prosarthroid than exarthroid, projecting as in *Macrophthalmus.* Chelipeds equal. Ambulatory feet rather stout, those of the second pair conspicuously the longest; meros-joints with membranaceous sides, or tympana occupying the entire faces; dactyli very small and slender. Sternum and male abdomen nearly as in *Macrophthalmus.*

This genus, although properly belonging to the family in which it is here placed, in its thick body, soft structure, and tympanum-like surfaces of the thigh-joints, will form a connecting link between the Macrophthalmidæ and the Dotillidæ.

It is an inhabitant of brackish waters on the shores of southeastern Asia.

157. ILYOPLAX TENELLA Stimpson

Ilyoplax tenella STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 98 [44], 1858.

Carapax nearly quadrangular, length to breadth as 1 : 1.54. Antero-lateral angles obtuse. Sides slightly convex and bordered by an

acute raised line or crest, which bifurcates at about the middle, the inferior fork, which is most prominent, passing to the base of the second pair of ambulatory feet, while the superior fork, which is more distinctly setose, passes to the base of the last pair. The surface of the carapax is indistinctly areolated, smooth and glossy along the median line, but toward the lateral margins somewhat uneven, with transverse tuberculated and setose lines; the tubercles not very conspicuous, but more so in some specimens than in others. Frontal region longitudinally furrowed at the middle. The corners of the front are dilated a little beneath the bases of the eye-peduncles. Latero-inferior regions not sulcated, but evenly covered with fine setiferous granules. Chelipeds rather large; hand smooth; fingers deflexed, slender, as long as the palm and curved inward as in *Helæcius*, with somewhat excavated extremities; dactylus with a strong tooth near the middle. Ambulatory feet partly tomentose and setose above; meros-joint in the first and second pairs densely tomentose on the posterior face.

Color dark brownish-olive above, bluish-white below; feet paler; chelipeds reddish; fingers in the male white. Dimensions of a male: Length of carapax, 0.27; breadth, 0.415 inch.

Found at Whampoa, China, along the banks of the Canton River (brackish water), living in holes in the mud, exposed at low water.

DOTILLIDÆ.

Genus DOTILLA Stimpson

The name *Doto,* originally proposed for this genus by De Haan, was previously used, as long ago as 1815, by Oken for a genus of nudibranchiate mollusks. A new designation was therefore proposed in the Proceedings of the Philadelphia Academy for April, 1858.

158. DOTILLA MYCTIROIDES Stimpson

Doto myctiroides MILNE EDWARDS, Mél. Carcin., 116, pl. IV, fig. 24.
Dotilla myctiroides STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 98 [44], 1858.

The chelopoda in this species are greatly elongated. The compressed meros-joint of the ambulatory feet is dilated and bears a very large oblong tympanum or membranaceous disk. The fourth joint of the male abdomen has an abrupt, setose extremity, somewhat like that of the penult joint in *Myctiris.*

Our specimen was taken in Gaspar Straits by Mr. Squires, of the steamer "John Hancock."

159. SCOPIMERA TUBERCULATA Stimpson

Scopimera tuberculata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 98 [44], 1858.

Carapax broad, but much narrower on the dorsal surface than at the bases of the anterior ambulatory feet. Length to greatest breadth as 1 : 1.66. Surface uneven, the branchial and hepatic regions being separated from each other and from the gastric and postmedian regions by well-marked though irregular sulci. The upper surface, with the exception of the broad and smooth postmedian region, is everywhere studded with protuberances and tubercles, irregular in their size and distance from each other. The lateral margins of the back are prominent, ciliated, and passing backward and downward are continuous with the suprapedal margins of the carapax. On each side beneath the dorsal margins there is a deep, smooth longitudinal sulcus. The sides are covered with setiferous granules, most crowded below. Orbits ample, oblique, well excavated, external angle forming a small tooth. External maxillipeds convex; meros partly granulated, more than half as large as ischium, and joined to it by an oblique suture; palpus rather exarthroid than prosarthroid, but joined at the summit of the meros. Chelipeds equal, elongated, more than twice as long as the carapax, but shorter than the first pair of ambulatory feet. Ambulatory feet tapering, sparsely fringed below with stiff blackish hairs; tympana nearly as in *S. globosa* or *Doto myctiroides*. Abdomen as in *S. globosa*. Dimensions of the body in a male: Length, 0.36; breadth at base of second ambulatory feet, 0.6 inch.

This species approaches *Doto* somewhat in character. It differs from De Haan's *S. globosa* in the character of the upper surface of the carapax and in the obliquity of the meros-joint in the outer maxillipeds.

It lives in holes in sandy-mud flats at and above low-water mark. Found in the inner harbor of Simoda, Japan.

MYCTIRIDÆ

Genus MYCTIRIS Latreille

160. MYCTIRIS LONGICARPUS Latreille

Myctiris longicarpus LATREILLE, Encyc. Méth., Ins., pl. CCXCVII, fig. 3. MILNE EDWARDS, Hist. Nat. des Crust., II, 37; Mél. Carcin., 118. DANA, U. S. Expl. Exped., Crust., I, 389.

This crab, when alive, is of an opaque light-blue color above and bluish-white below. The feet are white except at the joints, which

are pale reddish. It is very common on the shores of Botany Bay and Port Jackson, Australia, living on sandy beaches, in holes of slight depth, generally much above low-water mark. It is called "soldier crab" by the colonists.

161. MYCTIRIS BREVIDACTYLUS Stimpson

PLATE XIII, FIG. 4

Myctiris brevidactylus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 99 [45], 1858.

Carapax short, globular, nearly smooth. Breadth to length as 1 : 1.06. Branchial regions but little inflated, microscopically granulated. On the posterior or depressed portion of the gastric region there are two short, longitudinal depressed lines, parallel, one on each side. There is a short, slender, blunt spine on each side near the external angle of the orbit. Chelipeds nearly as in *M. longicarpus,* but stouter. Ambulatory feet also stouter than in the species just mentioned, with short and thick dactyli. The dactylus in the posterior pair is curved upward near the extremity, and trigonal in shape, with the angles ciliated.

Color of the carapax whitish blue, deeper about the middle of the back. Feet white, pale reddish near their bases. Dimensions of a male: Length of carapax, 0.682; breadth, 0.639 inch.

This species is easily distinguished from *M. longicarpus,* which it much resembles in general appearance, by the shorter and thicker terminal joints of the ambulatory feet. It may prove to be the *M. deflexifrons* of De Haan, but we can nowhere find a description of this species.

It is found in great numbers on low sandy-mud shores and flats in the lower half of the littoral zone. It occurred to us at Hongkong and among the Loo Choo Islands.

162. MYCTIRIS PLATYCHELES Milne Edwards

PLATE XIII, FIG. 5

Myctiris platycheles MILNE EDWARDS, Mélanges Carcinologiques, p. 118.

The description of Milne Edwards is as follows: "Carapace couverte de petits points granuleux, très espacés et très saillants. Pattes courtes et larges.—Port Western." It is not inconsistent with the characters of our crab, but there are several prominent distinctive characters not mentioned which render the identification, based upon so short a diagnosis, somewhat uncertain.

The branchial regions are prominently inflated above, forming subglobose projections, which are much more conspicuously granulated than the rest of the carapax. The gastric region is nearly smooth, bearing only a few scattered granuliform "points." In the compressed ambulatory feet the penult joint bears two prominent carinæ, the dactylus four carinæ. The meros-joint is somewhat inflated and granulated. The hectognathopoda are greatly expanded and protruding, so as to lie in planes almost longitudinally vertical. The rostrum is more pointed than in *M. longicarpus,* and there is a granulated projection instead of a spine exterior to the orbit. Color in life as in *M. longicarpus.* Size also about the same. Our specimens were taken on the shores of Botany Bay, in the third subregion of the littoral zone.

It is perhaps the same as *M. subverrucatus* White (Cat. Brit. Mus., 1847, p. 34), of which no description has been published. If it should prove distinct we would propose the name *M. prostoma.*

OCYPODIDÆ

Genus GELASIMUS Latreille

163. GELASIMUS VOCANS[1] (Rumph) Milne Edwards

Cancer vocans RUMPH (fide MILNE EDWARDS).
Gelasimus nitidus DANA, U. S. Expl. Exped., Crust., I, 316, pl. XIX, fig. 5.
Gelasimus vocans MILNE EDWARDS, Mél. Carcin., 109, pl. III, fig. 4.

Color of carapax in life bluish-gray or olivaceous, rather dark; sometimes mottled with white. Below bluish-white. Feet paler. Large hand white or light gray above, yellowish-green or deep orange below. Small hand bluish.

Found in its holes on coarse sandy shores not far below high-water mark in Napa Harbor, Loo Choo, and Hongkong Harbor, China.

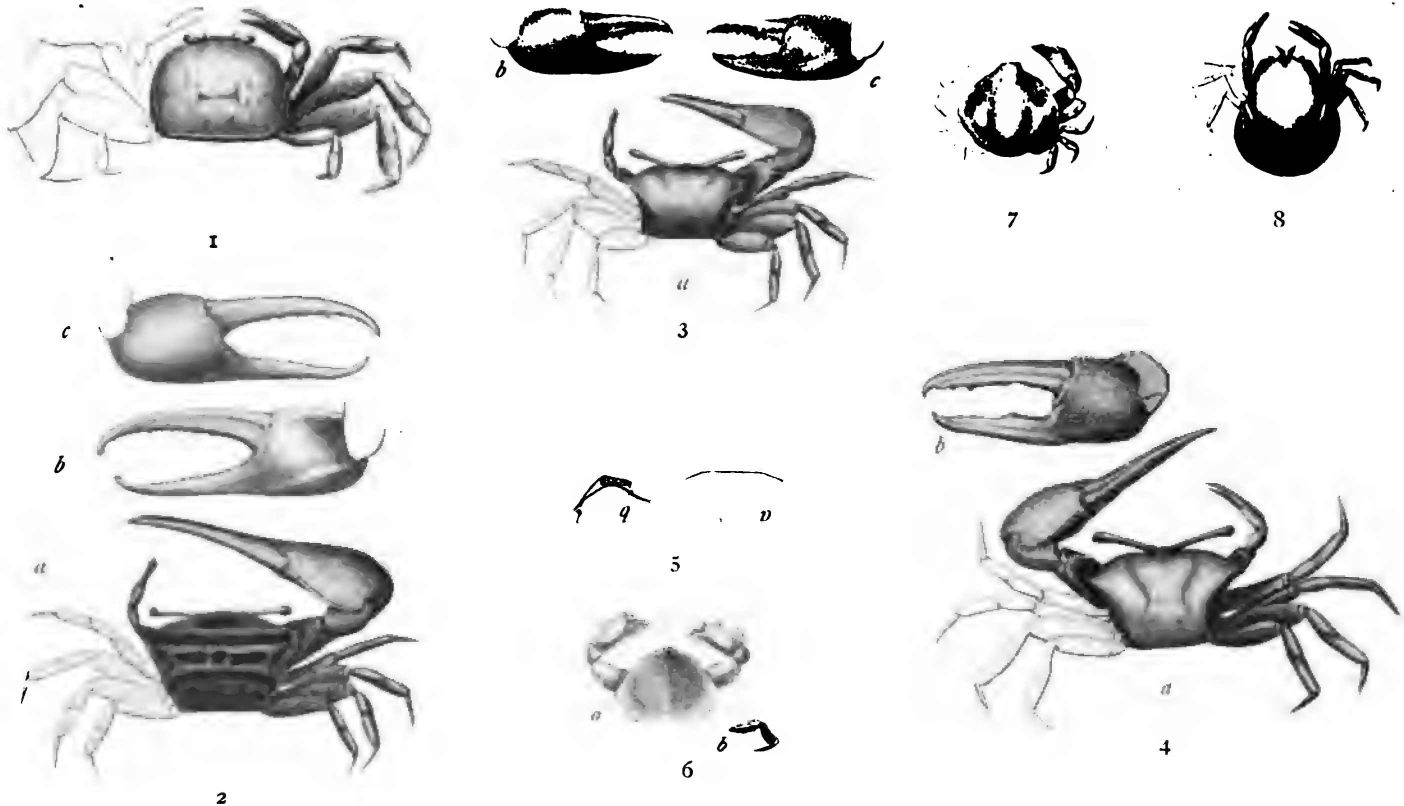
164. GELASIMUS DUBIUS[2] Stimpson

PLATE XIV, FIG. 4

Gelasimus dubius STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 99 [45]. 1858.

This species resembles *G. vocans* in shape and in the characters of the front, etc., except that the carapax is more narrowed posteriorly;

[1] *Uca marionis nitida* (Dana).
[2] *Uca dubia* (Stimpson).



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the frontal sulcus is deeper and the orbits more oblique. Length of the carapax to its breadth as 1 : 1.57. Antero-lateral angles very sharply prominent. Outer extremity of the crenulated inferior margin of the orbit angular. In the large cheliped the superior margin of the meros-joint is spinulose or denticulated at and near the summit, but there is no sharp conical tooth, as in *G. vocans*. The greater hand is well developed; outer surface of palm granulated or small-tuberculated; crest on the inner surface nearly as in *G. vocans*, but less prominent; fingers neither very broad nor much compressed, their external surface marked with a longitudinal sulcus, their inner margins irregularly denticulated, with two or three larger conical teeth. Meros-joint of ambulatory feet rather broad; dactyli as in *G. vocans*. Dimensions of a male: Length of carapax, 0.522; breadth, 0.82; length of great hand, 1.22; breadth, 0.44 inch.

This species differs from *G. acutus* in the more distinct regions of the carapax, the less distinct marginal lines, and in the compressed and hairy dactyli. It is perhaps the same as *G. forcipatus* Adams and White (Voy. Samarang, Crust., p. 50), but that species is described as having very distinct marginal lines on the sides.

It was found at Loo Choo in the usual station of the genus.

165. GELASIMUS ACUTUS[1] Stimpson

PLATE XIV, FIG. 3

Gelasimus acutus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 99 [45], 1858.

Carapax convex, very broad anteriorly and much contracted behind. Length to breadth as 1 : 1.72. Front as broad as in *G. tetragonon* and not dilated below. Antero-lateral angles acute. Surface smooth and nearly even; regions indistinct. Marginal lines very well marked. Inferior margin of orbit crenulated only toward its angular external extremity. A convex protuberance on the floor of the orbit at its inner extremity corresponds to the "lobe sous-orbitaire interne" of Milne Edwards. Beneath the infraorbital margin, separated by a smooth furrow, there is another distinct crest, nearly parallel to it. Large cheliped of the male moderately developed; outer surface of carpus and hand prominently granulated. Hand well armed within, the crests not very prominent, but tuberculated; fingers short, no longer than the palm, both sulcated externally, their inner margins rather strongly denticulated, teeth nearly

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[1] *Uca dussumieri* (Milne Edwards).

equal, a single larger one at the middle on the lower finger. Ambulatory feet smooth, naked; meros compressed, dilated; dactyli small and slender. Color white. Dimensions of the male: Length of carapax, 0.39; breadth, 0.67; length of greater hand, 0.83; breadth, 0.36 inch.

It differs from *G. forcipatus* Adams and White in having no "dilated lobe between the eyes" and no great tooth near the end of the fingers. The meros-joints of the walking-feet are less dilated than in *G. brevipes*.

Taken at Macao, China.

166. GELASIMUS SPLENDIDUS [1] Stimpson

PLATE XIV, FIG. 2

Gelasimus splendidus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 99 [45], 1858.

Carapax strongly convex in a longitudinal sense, its median dorsal outline forming almost a semicircle. It is very broad anteriorly (broadest at the prominent angles of the orbits) and considerably narrowed behind. Length to breadth as 1 : 1.6. Branchial regions not inflated. The lines bordering the anterior and antero-lateral margins are sharply raised. Front very broad, somewhat truncated below. The supraorbital margin is but slightly undulated, most so near its exterior extremity; both crests are minutely crenulated, and the lower or anterior crest is less convex than usual. The peduncles of the eyes are not very long, the eye falling a little short of the exterior extremity of the orbit. The exterior angle of the crenulated inferior margin of the orbit is broadly rounded, as in *G. palustris*. The large cheliped of the male is well developed; meros with obtuse, granulated angles, and no very prominent tooth at the summit; hand minutely granulated, with palm about two-thirds as long as the fingers, not strongly armed within, the inferior oblique crest prominent with a single row of granules, the crest at base of fingers nearly obsolete, the superior crest not bifurcated and scarcely tuberculated; fingers slender, smooth, strongly gaping, their inner margins evenly curved and minutely toothed, with two or three conical teeth a little larger than the rest; extremity of immovable finger longitudinally emarginated. Ambulatory feet naked; meros of moderate width; dactylus short, not compressed.

Colors: The carapax is of a light opaque-blue color, transversely

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[1] *Uca splendida* (Stimpson).

banded and spotted with black. Large cheliped pale red. Feet purplish, mottled. External maxillipeds light blue. Lower surface of body very pale bluish. Dimensions of a male: Length of carapax, 0.49; breadth, 0.78; length of large hand, 1.35; breadth, 0.48 inch.

This species is remarkable for its convexity and for the prominence, without acuteness, of the anterior angles of the carapax. It is allied to *G. gaimardi* and to *G. latreillei* of Milne Edwards (Mélanges Carcinologiques, p. 114), and may prove identical with one of these species, but the descriptions as yet published are too short for certain identification. From the first-mentioned species ours would appear to differ in having the front less prolonged and rounded below, and from the second in the greater length and the dentition of the pincers.

Our species inhabits salt marshes on the shores of Hongkong Harbor.

167. GELASIMUS PULCHELLUS[1] Stimpson

PLATE XV, FIG. 1

Gelasimus pulchellus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 100 [46], 1858.

Of this species several male specimens were collected. They are all of small size, but have the appearance of being nearly full grown. Carapax strongly convex, narrowed behind, broad in front, where it is prominent at the middle. Length to breadth as 1 : 1.51. Anterolateral angles acute, prominent. Marginal lines sufficiently distinct. Front prominent, broad, rounded below. Eye-peduncles long, the eyes reaching nearly, if not quite, to the extremities of the orbits. Outer angle of the acutely crenulated inferior margin of the orbit rounded. Large cheliped with nearly smooth surfaces, obsoletely granulated; hand armed within, the inferior crest prominent, granulated, the superior crest very sparsely granulated. There are two parallel crests at the base of the fingers, each ornamented with a single row of small tubercles. On the outer surface of the hand at the base of the immovable finger there is a small depressed area or shallow pit, like a cicatrix, of an ovate or triangular form, which is always present and affords a good specific character. The fingers are rather short, slightly compressed; the sides smooth; the inner margins denticulated, with two or three somewhat larger, conical teeth interspersed; one of these larger teeth is situated close to the

[1] *Uca pulchella* (Stimpson).

extremity of the immovable finger. The ambulatory feet are slightly hairy, the dactyli somewhat compressed.

The carapax is painted with deep blue markings; the large claw is light red. Dimensions of the male: Length of carapax, 0.398; breadth, 0.605; length of larger hand, 0.89; breadth, 0.33 inch.

This species is allied to *G. annulipes* in the shape of the carapax, etc. The double crest at the base of the fingers on the inner surface of the hand, and the cicatrix on the outer surface, will serve to distinguish it.

It is common at the Island of Tahiti, on the sandy and muddy banks of the lagoons.

168. GELASIMUS LACTEUS[1] De Haan

Gelasimus lacteus DE HAAN, Fauna Japonica, Crust., 54, pl. XV, fig. 5. MILNE EDWARDS, Mél. Carcin., 114, pl. IV, fig. 16.

This species is remarkable for its great breadth posteriorly. The interocular front is broad. The color in life is chalky white.

Found living in its holes in mud, among stones, above low-water mark on the shores of Cum-sing-moon and Macao, China.

Genus OCYPODE Fabricius

169. OCYPODE CURSOR[2] (Belon) De Haan

Cancer cursor BELON (fide MILNE EDWARDS).
Ocypode ippeus OLIVIER, MILNE EDWARDS, Hist. Nat. des Crust., II, 47.
Ocypode cursor DE HAAN, Fauna Japonica, Crust., 29. MILNE EDWARDS, Mél. Carcin, 106.

Taken at Porto Praya, Cape de Verde Islands. Habits as usual in the genus.

170. OCYPODE CERATOPHTHALMA (Pallas) Fabricius

PLATE XII, FIG. 2

Cancer ceratophthalmus PALLAS.
Ocypode ceratophthalmus FABRICIUS, Suppl., 347. DESMAREST, Consid. sur les Crust., 121, pl. XII, fig. 1. MILNE EDWARDS, Hist. Nat. des Crust., p. 48; Illust. Cuv. R. A. Crust., pl. XVII; Mél. Carcin., 105.
Ocypode brevicornis DANA, U. S. Expl. Exped., Crust., I, 326, pl. XX, fig. 3.

The length of the terminal process, or horn of the eye, affords no distinctive character in the genus *Ocypode,* as this is generally want-

[1] *Uca lactea* (de Haan).
[2] *Ocypode ippeus* Olivier.

ing in the young, and increases in size with age. This fact seems to have been first noticed by Gerstæcker. The examination of numerous specimens of all ages, taken in the harbor of Hongkong, enables us to determine that the growth of the process may commence earlier in some specimens than in others, but never before the body of the individual reaches the length of two-thirds of an inch. So that specific distinctions must rest mainly upon other characters, for a difference in the length of the horn, even in specimens of the same age or size, does not necessarily indicate specific diversity.

It is probable that several spurious species have been founded upon the different ages of *O. ceratophthalma*, to designate which, however, an examination of the original specimens of the various authors is necessary.

The figures represent the appearance of the eye at different ages.

This species in life is of a yellowish-white or light-gray color, often finely punctate, and in the adult marked with two oblong brown spots near the middle of the carapax. The parts about the mouth are blotched with reddish-brown. Eye-peduncles brownish. Hands white. There is sometimes a red spot on the third joint of the feet.

It was found by us at Hongkong, Loo Choo, the Bonin Islands, the Hawaiian Islands, and at Tahiti. It lives, like its congeners, in holes in the beaches at and above high-water mark.

171. OCYPODE CONVEXA Stimpson

PLATE XV, FIG. 3

Ocypode convexa STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 100 [46], 1858.

A single specimen only, a female, of this species was taken, which may be thus described: Carapax much swollen, posteriorly broad and spreading over the bases of the feet. Proportion of length to breadth, 1 : 1.07. Surface nearly smooth, the granules with which it is covered being much flattened. Antero-lateral angles prominent, acute; the margin immediately behind these angles straight or slightly concave. Internal suborbital lobe slender, dentiform, bifurcated. Infraorbital margin with a notch near the middle. Buccal area large, with convex sides. External maxillipeds strongly protuberant, not closely fitting to each other within; their surface nearly smooth, and more or less glossy; meros but little depressed at the middle. Larger hand rather short and broad, dilated below; fingers much compressed; outer surface depressed-granulated; edges small toothed. Fingers of the smaller hand compressed and produced,

with somewhat truncated extremities. Ambulatory feet, with the exception of the terminal joints, naked, nearly smooth, but slightly rugose, the rugæ being similar in character to those in *O. ceratophthalma,* but much less strongly developed. Abdomen (of the female) with the penult joint deeply sinuated; the terminal joint set in the bottom of the sinus, and reaching fully to, or a little beyond, the bases of the maxillipeds. Dimensions of the carapax: Length, 0.92; breadth, between the orbital angles, 0.96 inch.

It differs from *O. cordimana* in the character of the maxillipeds, smaller hand and feet.

Found at Simoda, Japan.

172. OCYPODE CORDIMANA Desmarest

PLATE XV, FIG. 2

Ocypode cordimana DESMAREST, Consid. sur les Crust., 121. MILNE EDWARDS, Mél. Carcin., p. 107.

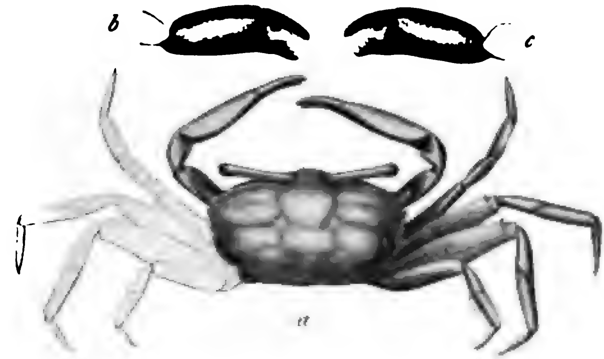
The species here referred to *O. cordimana,* is distinguished by its convex, faintly granulated carapax, little oblique orbits, little prominent orbital angle, immediately behind which the lateral margin is convex. The dentiform internal suborbital lobe is compressed, rather broad and smooth, not denticulated. The buccal area is small, narrowed anteriorly, with straight sides, and is neatly covered by the external maxillipeds, which are not protuberant, as in most species. The surface of the maxillipeds is glossy, with a few sparsely scattered granules or points; the meros-joint is depressed in the middle, with a ridge on either side, as in *O. ceratophthalma,* but not much granulated. The feet are nearly smooth, although there are indications, on the meros- and carpus-joints, of the spinules mentioned in Milne Edwards's description. They are somewhat pilose toward their extremities. Dactylus of last pair much curved upward and outward. Abdomen of the male much broader than in other species.

Found at Hongkong and at Loo Choo.

173. OCYPODE LÆVIS Dana

Ocypode lævis DANA, U. S. Expl. Exped., Crust., I, 325, pl. XX, fig. 2.

A small, well marked species, easily distinguished by the character of the larger hand, which is much dilated below, and has very short and thick fingers. Our specimen is somewhat larger than those found by Dana.



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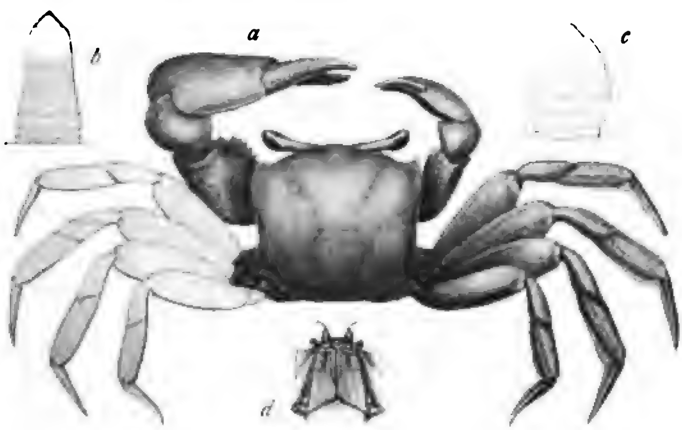

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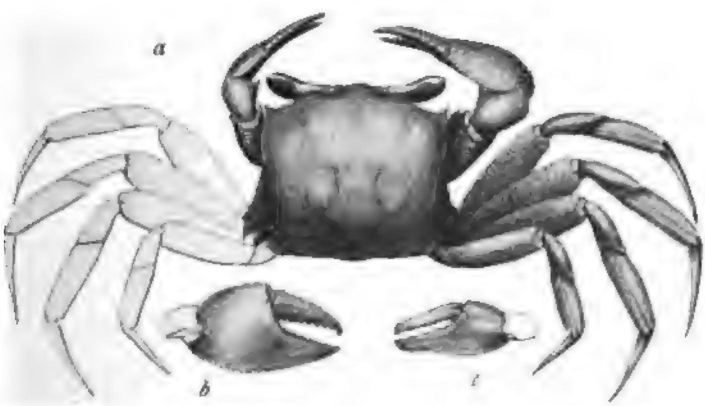

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CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

It is distinguished from *O. cordimana* by the projecting orbital angles and by the smoothness of the edges of the hands.

Taken at Hilo, Island of Hawaii.

GECARCINIDÆ

Genus CARDISOMA Latreille

174. CARDISOMA GUANHUMI (Marcgrave) Latreille

Cancer guanhumi MARCGRAVE.
Cardisoma guanhumi LATREILLE, MILNE EDWARDS, Hist. Nat. des Crust., II, 24; Illust. Cuv. R. A., Crust., pl. XX; Mél. Carcin, p. 170.

A male individual, probably of this species, was found in its hole in a cocoanut grove near the town of Porto Praya, Cape de Verde Islands. In this specimen the carapax is exceedingly smooth, both above and at the sides, and the antero-lateral line can scarcely be traced; these characters we find in adult males of *C. guanhumi* from the American shores. But in these western specimens one of the hands is greatly developed in size, with broadly gaping fingers, while in the expedition specimen the hands resemble those of the young of *C. guanhumi,* in which the lateral line is distinct. The wide difference in locality would lead us to consider the species different, but we do not venture to separate it without seeing additional examples.

175. CARDISOMA OBESUM[1] Dana

Cardisoma obesum DANA, U. S. Expl. Exped., Crust., I, 375, pl. XXIV, fig. I.
Cardisoma urvillei MILNE EDWARDS, Mélanges Carcinologiques, p. 170.

This species was found living in holes in the gardens and along the streets in great numbers at Papiete, Island of Tahiti.

176. CARDISOMA HIRTIPES[2] Dana

Cardisoma hirtipes DANA, U. S. Expl. Exped., Crust., I, 376, pl. XXIV, fig. 2.

Color in life reddish-brown; feet and inferior surface yellow. We can discover no essential difference between the Loo Choo specimen and those described by Dana from the Fiji Islands, with the single exception that in ours, which is a male, the left hand is much larger than the right, while in Dana's the hands are equal.

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[1] *Cardisoma carnifex* (Herbst).
[2] *Cardisoma rotundum* (Quoy and Gaimard).

C. frontalis Milne Edwards (Mél. Carcin., p. 170) must be closely allied to, if not identical with, this species, but appears to have two more complete rows of spines on the upper side of the penult joint of the walking-feet.

This species was found in the paddy-fields at Loo Choo. The fields lie mostly under water, and the animal probably burrows in their banks.

BOSCIADÆ

Genus POTAMOCARCINUS Milne Edwards

177. POTAMOCARCINUS ARMATUS[1] Milne Edwards

Potamocarcinus armatus Milne Edwards, Arch. du Museum d'Hist. Nat., VII, p. 174, pl. XIII, fig. 3.

We have but one specimen of this species, a small male, half an inch in length. It differs somewhat from the large female described by Milne Edwards, in that the carapax is punctated and, toward the lateral margins, somewhat granulated. The second and third antero-lateral teeth are bifid. Dactyli scarcely quadrangular, almost rounded; also smaller and less spinulose.

It was found at Omotepec Island, in Lake Nicaragua, by Mr. Charles Wright, botanist of the expedition.

THELPHUSIDÆ

Genus GEOTHELPHUSA Stimpson

This name is proposed for that group of *Thelphusæ* which is characterized by the obsolescence of the postfrontal crest and the epibranchial teeth of the antero-lateral margins. In the shape of the carapax they have some resemblance to the Gecarcinidæ, and they approximate to that family also in their habits, frequenting the dry land much more constantly than the typical *Thelphusæ*.

178. GEOTHELPHUSA DEHAANI[2] Stimpson

Plate XVII, Fig. 2

Thelphusa berardi De Haan, Fauna Japonica, Crust., p. 52, pl. VI, fig. 2 (non Auct.).

Thelphusa dehaanii White, Cat. Brit. Mus., 1847, p. 30. Milne Edwards, Mél. Carcin., p. 178.

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[1] *Potamocarcinus nicaraguensis* Rathbun.

[2] *Potamon (Potamonautes) dehaanii* (White).

Geothelphusa dehaani STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 101 [47], 1858.

We give below the measurements of our specimen, a male. The antepenult joint of the feet is not pilose:

Length of the carapax, 1.5; breadth, 1.9; length of greater hand, 2.02; breadth, 1.1; length of smaller hand, 1.2; breadth, 0.53 inch.

It was found on one of the Amakirrima Islands (near Loo Choo) by the officers of the "John Hancock."

179. GEOTHELPHUSA OBTUSIPES[1] Stimpson

Geothelphusa obtusipes STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 101 [47], 1858.

Two females of this species were found. Carapax much flattened above and posteriorly; anteriorly much curved. Length to breadth as 1 : 1.26. Surface regular, covered with crowded punctations. Anterior gastric lobules more prominent than in *G. dehaani*. Transverse suture at the middle of the carapax deeply impressed. Sides rugose, with transverse striæ; antero-lateral crest prominent crenulated. The carpus-joint in the chelipeds is somewhat rugose above, within small-tuberculated and bidentate, the inferior tooth small; the hands and fingers are sparsely tuberculated. Ambulatory feet slender; penult joint spinulose above and below; dactyli crowdedly spinulose, especially toward the extremities, the terminal unguiculus not reaching beyond the tips of the adjacent spinules, which gives the tips of the feet an obtuse appearance.

Dimensions of the carapax: Length, 0.722; breadth, 0.915 inch.

Found on the Island of Ousima.

Genus THELPHUSA Latreille

180. THELPHUSA PERLATA[2] Milne Edwards

Thelphusa perlata MILNE EDWARDS, Hist. Nat. des Crust., II, 13. KRAUSS, Sudafr. Crust., p. 37.

This crab was caught in a small stream near Constantia, Cape of Good Hope.

[1] *Potamon (Geothelphusa) obtusipes* (Stimpson).

[2] *Potamon (Potamonautes) perlatus* (Milne Edwards).

Genus PARATHELPHUSA Milne Edwards

181. PARATHELPHUSA SINENSIS[1] Milne Edwards

Parathelphusa sinensis MILNE EDWARDS, Archives du Museum d'Hist. Nat., VII, 173, pl. XIII, fig. 2; Mél. Carcin., p. 179.

Carapax strongly convex, four-fifths as long as broad, scarcely narrowed posteriorly. Postfrontal crest interrupted. Antero-lateral margin short, four-toothed, including the angle of the orbit: teeth about equal, sharply projecting, with smooth margins. The distance from the orbital tooth to the tip of the posterior tooth equals one-fourth the width of the carapax. Front horizontal, projecting, broad, lightly undulated, margin not at all angular over the antennæ. Postero-lateral surface striated transversely; striæ about eight in number. Subhepatic region tuberculated behind the orbit; tubercles somewhat irregularly arranged, small, subequal, and angular. Chelipeds minutely rugate transversely; a small spine on the meros and one on the carpus. Meros-joint of ambulatory feet bearing a sharp spine near the summit.

Color in life dark brownish-olive above; the middle of the carapax and the feet punctate with red. Below pale ferruginous. Dimensions of one of our specimens, a female: Length of carapax, 1.08; breadth, 1.36 inches.

Taken in the river at Whampoa, China. Milne Edwards gives "Mers de la Chine" as the habitat. But it is certainly an inhabitant of fresh, or at least brackish, waters.

GRAPSIDÆ

Genus METOPOGRAPSUS Milne Edwards

182. METOPOGRAPSUS THUKUHAR[2] Milne Edwards

Grapsus thukuhar OWEN, Zoöl. of Beechey's Voy., p. 80, pl. XXIV, fig. 3.
Pachygrapsus parallelus RANDALL, Jour. Acad. Nat. Sci. Phila., VIII, 124.
Goniograpsus thukujar DANA, U. S. Expl. Exped., Crust., I, 344.
Metopograpsus thukuhar MILNE EDWARDS, Mélanges Carcinologiques, p. 131.

In this species the internal suborbital lobe sometimes joins the front, but there is usually a sufficiently distinct though narrow hiatus between them.

[1] *Potamon (Parathelphusa) sinensis* (Milne Edwards).
[2] *Metopograpsus messor* (Forskål).

The color in life is bluish-gray above, clouded with blackish punctæ. Sometimes entirely black. Outer and under sides of hands reticulated with purplish. Below white.

It inhabits the shores of protected harbors, among stones. A lighter-colored variety lives in sandy coves, along the edges of salt marshes. It also frequents the vicinity of the mouths of small streams.

Found by us at Loo Choo, at the Bonin Islands, the Hawaiian Islands, and at Tahiti. The species appears to be found at all the tropical Pacific islands, both north and south of the equator.

183. METOPOGRAPSUS QUADRIDENTATUS Stimpson.

PLATE XVI, FIG. 2

Metopograpsus quadridentatus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 102 [48], 1858.

Carapax quadrangular; proportion of length to breadth, 1 : 1.22. It is considerably narrowed behind, rather smooth, glossy, very moderately striated anteriorly and at the sides; the posterior half perfectly smooth about the middle. Pregastric lobules little prominent. Frontal region smooth, concave or transversely shallow, channel-shaped. Front broad; margin undulated and sharply crenulated. Lateral margin with one very sharp tooth behind the orbital angle. Inner margin of meros-joint of the chelipeds with three or four small tuberculiform teeth near the base and four acute teeth at the anterior angle, the outer tooth very prominent, compressed, with convex outer margin. Carpus with somewhat scabrous or squamous upper surface, and a short, vertical 2- or 3-toothed crest at the inner angle. Hand obsoletely squamous or tuberculous above, below, and within; outer surface smooth. Ambulatory feet sparsely hairy toward extremities; terminal spines or teeth of meros, above and below, strong and sharp. Dimensions of the male: Length of carapax, 0.74; breadth, 0.9; breadth of front, 0.54; length of ambulatory foot of the second pair, 1.4 inches.

The only other quadridentate *Metopograpsus* known is *M. oceanicus* Milne Edwards (*Grapsus oceanicus* Hombr. and Jacq., Voy. au Pole Sud, Crust., pl. VI, fig. 9), from which the species above described differs widely in its smoother carapax and hands.

It was found at Cum-sing-moon, near Macao, China, running about between tide marks.

Genus PACHYGRAPSUS (Randall) Stimpson

184. PACHYGRAPSUS MARMORATUS Stimpson

Cancer marmoratus FABRICIUS, HERBST.
Grapsus varius LATREILLE, MILNE EDWARDS, Hist. Nat. des Crust., II, 88.
Goniograpsus varius DANA, U. S. Expl. Exped., Crust., I, 344.
Leptograpsus marmoratus MILNE EDWARDS, Mélanges Carcinologiques, p. 137.
Pachygrapsus marmoratus STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 102 [48], 1858.

Our specimens are small, none reaching the length of one inch, and they are more depressed than any Mediterranean specimens which have come under our notice.

They were found at the Island of Madeira.

185. PACHYGRAPSUS CRASSIPES Randall.

Pachygrapsus crassipes RANDALL, Jour. Acad. Nat. Sci. Phila., VIII, 127. STIMPSON, Crust. Pacif. Coast N. A., p. 27.

Taken by us at Simoda, Japan. I am unable to find a distinguishing character, however minute, between the specimens from Japan and those from California.

186. PACHYGRAPSUS SIMPLEX[1] Stimpson

Goniograpsus simplex DANA, U. S. Exploring Expedition, Crust., I, 344, pl. XXI, fig. 8.
Pachygrapsus simplex STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 102 [48], 1858.

Our specimens of this species were taken at Madeira. They agree exactly with those of Dana, who gives, with a doubt, Rio Janeiro as the locality of his specimens. But they were probably also from Madeira, as the U. S. Exploring Expedition stopped at that island several days before proceeding to Rio.

187. PACHYGRAPSUS INNOTATUS[2] Stimpson

Goniograpsus innotatus DANA, U. S. Expl. Exped., Crust., I, 345, pl. XXI, fig. 9.
Pachygrapsus innotatus STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 102 [48], 1858.

Our specimens agree in every respect with those of Dana, except in the more rugose carpus.

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[1] *Pachygrapsus maurus* Lucas.
[2] *Pachygrapsus transversus* Gibbes.

They were found in clefts of the surf-washed rocks above low-water mark at Funchal, Madeira. The remark with regard to the reputed locality of the last species applies equally well to this.

188. PACHYGRAPSUS LÆVIMANUS [1] Stimpson

Pachygrapsus lævimanus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 102 [48], 1858.

This species has much resemblance to *P. innotatus* and *P. rugulosus* of the Atlantic shores, but the carapax is somewhat narrower and smoother, the carpus nearly smooth, and the raised line on the outer surface of the hand, parallel to its lower margin, is obsolete or nearly so. The hiatus between the suborbital lobe and the front is much wider and the basal joint of the antennæ broader. The ground color of the carapax is bluish-white, but this tint is almost concealed by crowded transverse black lines and blotches. Feet brownish. Beneath nearly white. Dimensions of the carapax in a male: Length, 0.54; breadth, 0.65 inch. Proportion, 1 : 1.204.

It was found among stones at half-tide in Sydney Harbor (Port Jackson), Australia.

189. PACHYGRAPSUS PLICATUS Stimpson

Grapsus plicatus MILNE EDWARDS, Hist. Nat. des Crust., II, 89; Mélanges Carcinologiques, p. 136.
Goniograpsus plicatus DANA, U. S. Expl. Exped., Crust., I, 343.

A single specimen, a female, was found at Loo Choo. In this the transverse plications are much more strongly marked than in specimens from the Hawaiian Islands, particularly those on the superior surface of the meros-joint of the posterior pair of feet.

Genus LEPTOGRAPSUS (Milne Edwards) Stimpson

190. LEPTOGRAPSUS VARIEGATUS (Fabricius) Milne Edwards

Cancer variegatus FABRICIUS.
Grapsus variegatus LATREILLE, MILNE EDWARDS, Hist. Nat. des Crust., II, 87.
Leptograpsus variegatus MILNE EDWARDS, Mélanges Carcinologiques, p. 137.

Colors in life: The carapax is bluish-gray, everywhere transversely lineated and blotched with black; feet often reddish.

This species was found in considerable numbers at Port Jackson, Australia, running over the rocks at and above half-tide mark.

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[1] *Pachygrapsus transversus* Gibbes.

Genus GRAPSUS (Lamarck) Milne Edwards

191. GRAPSUS RUDIS[1] Milne Edwards

Grapsus rudis MILNE EDWARDS, Hist. Nat. des Crust., II, 87; Mélanges Carcinologiques, p. 134.
Grapsus hirtus RANDALL, Jour. Acad. Nat. Sci. Phila., VIII, 124.

Colors of the adult in life: Carapax above dark olive, with scattered patches of white dots; below, mouth and parts adjacent reddish, with the exception of the epistome and meros-joint of the maxillipeds, which are bluish. Abdomen bluish-white. Feet reddish above, greenish-white below. Hands externally of a deep blood color; tips of fingers white. In the largest of our specimens, a female, the carapax measured 2.73 inches in length and 2.8 inches in breadth.

This crab runs with greater velocity than any other seen during the cruise. It is very abundant about the larger rocks, and the young are sometimes found on stony and pebbly beaches. Found by us in Port Lloyd, Bonin Islands.

192. GRAPSUS STRIGOSUS (Herbst) Latreille

Cancer strigosus HERBST.
Grapsus strigosus LATREILLE, MILNE EDWARDS, Hist. Nat. des Crust., II, 87; Mél. Carcin., p. 135.
Goniopsis strigosus DE HAAN, Fauna Jap., Crust., 33.

In this species the ambulatory feet are broad and shorter than twice the breadth of the carapax. The posterior half of the carapax at the middle, for more than one-third its breadth, is quite smooth. The color in life is reddish and bluish above, mottled; below white.

It was found in the usual station on ocean shores at Loo Choo, Hongkong, and in Gaspar Straits.

193. GRAPSUS WEBBI[2] Milne Edwards

Grapsus strigosus BRULLÉ, Webb and Berthelot, Canaries, Crust., p. 15.
Grapsus webbi MILNE EDWARDS, Mélanges Carcinologiques, p. 133.

Found in Porto Praya, Cape de Verde Islands; also common at Madeira.

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[1] *Grapsus grapsus tenuicrustatus* (Herbst).
[2] *Grapsus grapsus* (Linnæus).

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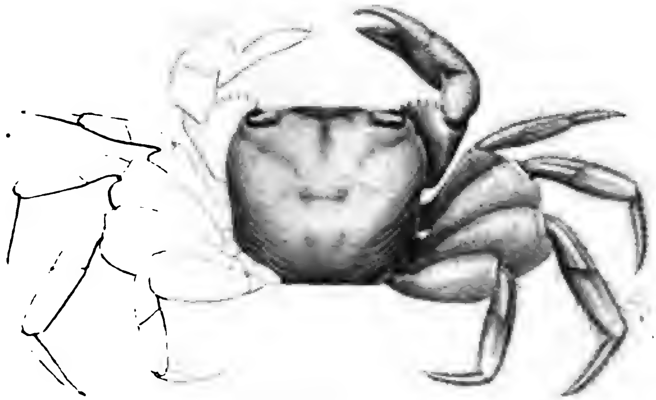

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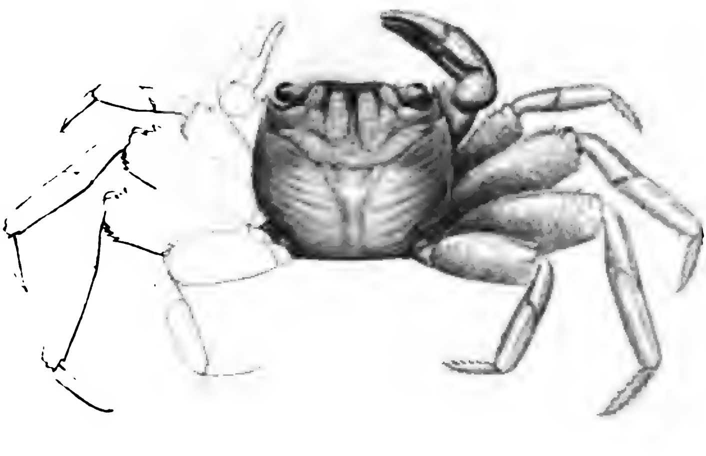

4

CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

194. GRAPSUS LONGIPES[1] Stimpson

Grapsus longipes STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 102 [48], 1858.

This species is closely allied to *G. strigosus,* the carapax showing nearly the same characters in every respect, except in being somewhat narrower anteriorly and a little more depressed across the median region. In the proportions of the ambulatory feet, however, considerable difference is perceptible, as they are much more slender than in *G. strigosus,* and more than twice the breadth of the carapax in length. The dactyli are more spinulose than in *G. longitarsis* Dana, the front more expanded, the gastric region less tuberculous, and the teeth or spines at the inferior extremity of the meros of the walking feet longer. The dimensions of a male specimen are as follows: Length of carapax, 1.22; breadth, 1.34 inches.

It was found at Kikaisima and at Hongkong.

195. GRAPSUS SUBQUADRATUS[2] Stimpson

PLATE XVI, FIG. 4

Grapsus subquadratus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 103 [49], 1858.

Allied to *G. strigosus* in the characters of the epistome, etc. Carapax subquadrate; length to breadth, as 1 : 1.13. It is broader in front than in *G. strigosus,* and the sides are less arcuated. The transverse striæ of the branchial regions are strongly marked, and extend across nearly the whole width of the carapax, leaving only the narrow depressed postcardiac region smooth, and even this portion of the surface is obsoletely squamous. Pregastric region strongly tuberculated, tubercles very numerous and subcristiform. Frontal region short and considerably tuberculated. Frontal margin crenulated. Inner tooth of carpus spiniform, very long, slender, and sharp. Ambulatory feet in length equaling just twice the width of the carapax; spines at inferior extremity of meros rather strong; dactyli longer than in *G. strigosus.* Dimensions of carapax in the male: Length, 1.11; breadth, 1.26 inches.

It is allied to *G. longitarsis* in the character of the front and dactyli, but the branchial striæ are much more produced inward.

It was found under stones below half-tide mark on the ocean shore at Hilo, Island of Hawaii.

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[1] *Grapsus strigosus* (Herbst).

[2] *Grapsus longitarsis* Dana.

Genus GEOGRAPSUS Stimpson

The characters of this genus are given in the synopsis, page 101 [47]. It is sufficiently distinguished from *Grapsus* proper, in which it is included by Milne Edwards, not only by its terrestrial habits (which seem to have been hitherto unknown), but also in the shorter, thicker body, shorter suborbital lobes, smaller antennæ, and the smoothly rounded inferior extremity of the meros-joint of the walking feet.

196. GEOGRAPSUS RUBIDUS [1] Stimpson

PLATE XVI, FIG. 3, 3*a*

Geograpsus rubidus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 103 [49], 1858.

Carapax moderately convex, widening considerably immediately behind the second lateral tooth, so that the sides are anteriorly convex and posteriorly slightly concave. Proportion of length to breadth, 1 : 1.17. Transverse striæ sharp, both anteriorly and posteriorly. Anterior gastric lobules sufficiently prominent. Frontal margin rather strongly crenulated. Surface of the meros-joint of the outer maxillipeds conspicuously striated. Meros-joint of chelipeds broad, with seven generally equal teeth on its anterior margin. Upper surface of hand obliquely striated, striæ tuberculated. Lower surface of hand marked with strong, regular, somewhat distant striæ. Ambulatory feet sparsely provided with long setæ; the meros very thin and much dilated; dactyli as long as or longer than the penult joint.

In life the carapax is of a deep red or mahogany color above, shining, becoming rather yellowish or orange toward the margins. Feet paler. Hands often yellow. Color beneath yellowish-white. Dimensions of the carapax in a male: Length, 1.12; breadth, 1.31 inches.

This species is allied to *G. crinipes* Dana, in its long dactyli, but may be distinguished by its more convex sides and the stronger and more distant striæ on the inferior surface of the hand.

It was found on Peel Island, one of the Bonin group, in October. It usually occurred among damp leaves or under stones, most frequently along the banks of mountain streams. It was sometimes found near the seashore, and occasionally at great elevations.

[1] *Geograpsus grayi* (Milne Edwards).

Genus NAUTILOGRAPSUS Milne Edwards

197. NAUTILOGRAPSUS MINUTUS[1] Milne Edwards

Cancer minutus LINNÆUS.
Grapsus cinereus SAY.
Nautilograpsus minutus MILNE EDWARDS, Hist. Nat. des Crust., II, 90; Mél. Carcin., p. 140.
Planes minutus BELL, DANA, U. S. Expl. Exped., Crust., I, 346.

Our largest specimen, a male, has the following dimensions: Length of carapax, 0.74; breadth, 0.79 inch. It is, therefore, not "beaucoup plus longue que large," as stated by Milne Edwards. The tooth behind the orbital angle is often nearly obsolete.

It is common on floating logs, seaweed (*Sargassum*), etc., in the North Atlantic between the 20th and 36th parallels of latitude. We did not observe it in the South Atlantic.

198. NAUTILOGRAPSUS ANGUSTATUS[1] Stimpson

PLATE XVI, FIG. 1

Nautilograpsus angustatus STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 103 [49], 1858.

Carapax smooth, narrow; proportion of breadth to length, 1 : 1.14. Branchial regions lightly striated transversely. Gastric lobules sufficiently distinct, but not prominent. Front narrow, much advanced, its margin lightly sinuated. Frontal region concave. Lateral margins nearly straight, parallel; a single small tooth behind the orbital tooth; margin acute between the teeth and for a little distance behind the posterior tooth, terminating at a slight oblique sulcus on the branchial region, perhaps indicating a third, obsolete tooth. Behind this point the margins are obtuse. Ambulatory feet rather less broad than in other species of the genus. The dimensions of our unique (female) specimen, which is probably immature, are: Length of carapax, 0.24; breadth, 0.21 inch.

It differs from *N. pusillus* in its less prominent second marginal tooth; from *N. cyaneus* in its more advanced front and less smooth surface. From both these species, and from *N. minutus,* it differs in its narrower carapax.

It was taken in the North Pacific Ocean, in latitude 34° N., longitude 151° W.

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[1] *Planes minutus* (Linnæus).

Genus PLAGUSIA Latreille

199. PLAGUSIA TOMENTOSA[1] Milne Edwards

Cancer chabrus LINNÆUS, Syst. Nat., 1044 (*fide* WHITE).
Plagusia tomentosa MILNE EDWARDS, Hist. Nat. des Crust., II, 92. McLEAY, in Smith's Illust. Zoöl. S. Afr., Annulosa, p. 66. DANA, U. S. Expl. Exped., Crust., I, 370.
Plagusia capensis DE HAAN, Fauna Jap., Crust., p. 58.
Plagusia chabrus WHITE, Cat. Brit. Mus., 1847, p. 42.

White refers this species, perhaps justly, to the *Cancer chabrus* of Linnæus. But the identification does not appear to rest upon comparison of the original specimens, and until this is made we prefer to use a name to which we can refer with certainty.

It is rather common about the rocks at half-tide in Simon's Bay, Cape of Good Hope.

200. PLAGUSIA DENTIPES De Haan

Plagusia dentipes DE HAAN, Fauna Japonica, Crustacea, p. 58, pl. VIII, fig. 1. MILNE EDWARDS, Mélanges Carcinologiques, p. 144.

Young specimens, probably of this species, were taken at Simoda.

201. PLAGUSIA SQUAMOSA[2] (Herbst) Dana

Cancer squamosus HERBST, Naturg. d. Krabben u. Krebse, I, 260, pl. XX, fig. 113.
Plagusia squamosa DANA (non M. EDW.), U. S. Expl. Exped., Crust., I, 368.

The Atlantic form differs constantly from the East Indian species usually called *Plagusia squamosa* in the dentation of the superior lobe or crest of the ischium-joint of the second and third ambulatory feet, which is always armed with two or three teeth. Herbst's figure represents this species, to which we would therefore restrict his name *squamosus*, notwithstanding that he gives the East Indies as its habitat.

It is common at Madeira.

202. PLAGUSIA ORIENTALIS[3] Stimpson

? *Plagusia tuberculata* LAMARCK, An. s. vert., V, 247.
Plagusia squamosa MILNE EDWARDS, Hist. Nat. des Crust., II, 94; Mél. Carcin., 144.

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[1] *Plagusia chabrus* (Linnæus).
[2] *Plagusia depressa* (Fabricius).
[3] *Plagusia tuberculata* Lamarck.

Plagusia orientalis STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 103 [49], 1858.

In this species the superior lobe of the ischium in the second and third pairs of walking feet is prominent and dentiform, but never denticulated—at least not in any of the specimens which we have seen.

The name *P. tuberculata* was applied by Lamarck by mistake to a specimen in which the pubescence had been rubbed off the carapax. This specimen may have belonged to this species, but in the uncertainty we have thought best to apply a new name.

The species was found by us at the Hawaiian Islands and on the outer shores of Hongkong.

203. PLAGUSIA DEPRESSA[1] (Fabricius) Latreille

Cancer depressus FABRICIUS, Suppl., 343. HERBST, Naturg. d. Krabben u. Krebse, I, 117, pl. III, fig. 35.
Grapsus depressus LATREILLE, Hist. Crust. et Ins., VI, 66.
Plagusia immaculata LAMARCK, An. s. vert., v, 247.
Plagusia depressa LATREILLE, Encyc. Méth., x, 147. MILNE EDWARDS, Hist. Nat. des Crust., II, 93; Mél. Carcin., p. 145. DANA, U. S. Expl. Exped., Crust., I, 369.
Philyra depressa DE HAAN, Fauna Jap., Crust., 31.

This species in life is elegantly variegated with crimson and yellowish. Specimens from Hongkong and Loo Choo are much smoother than others. Besides these localities, it was found by Mr. Squires, of the "Hancock," abundantly in Gaspar Strait, sometimes "attached to floating wood," and by Lieut. Van Wycke, of the "Porpoise," at Tomboro, or New Ireland.

Genus ACANTHOPUS De Haan

204. ACANTHOPUS PLANISSIMUS[2] (Herbst) Dana

Cancer planissimus HERBST, Naturg. d. Krabben u. Krebse, III, 3, pl. LIX, fig. 3.
Plagusia clavimana DESMAREST, MILNE EDWARDS, *et al.*
Acanthopus clavimanus DE HAAN, Fauna Jap., Crust., p. 30.
Acanthopus planissimus DANA, U. S. Expl. Exped., Crust., I, 373. MILNE EDWARDS, Mél. Carcin., p. 146.

The following are the life colors of a specimen from Port Lloyd, found by Mr. Kern: Carapax above bright red, inclining to orange, with median bluish-white line, from which two bluish-white patches

[1] ? *Plagusia tuberculata* Lamarck.
[2] *Percnon planissimum* (Herbst).

diverge obliquely forward. Feet lineated with darker red. Below everywhere bluish-white.

It was found in the Pacific at Port Lloyd, Bonin Islands, and at Hawaii; in the Atlantic at Madeira. We cannot distinguish the Madeira specimens from those found in the Pacific by any constant character, though it is not improbable that such will be found when a sufficiently large series of examples from both regions shall be examined.

These crabs are found under stones on ocean shores, and are very active, sliding out of sight very quickly when exposed in their haunts.

Genus VARUNA Milne Edwards

205. VARUNA LITTERATA (Fabricius) Milne Edwards

Cancer litteratus FABRICIUS, HERBST, Naturg. d. Krabben u. Krebse, III, 58, pl. XLVIII, fig. 4.

Varuna litterata MILNE EDWARDS, Dict. class. d'Hist. Nat., XVI, 511, 1830; Hist. Nat. des Crust., II, 95; Mél. Carcin., 142.

Trichopus litteratus DE HAAN, Fauna Jap., Crust., 32. DANA, U. S. Expl. Exped., Crust., I, 336.

Among a large number of specimens collected by the expedition there are none with spines upon the anterior margin of the meros-joint in the chelipeds. Perhaps this is a character only found in old males, as there are no males in our collection much exceeding an inch in length, although we have many large females.

The coloration is very uniform in this species—yellowish-brown above and light yellow below; the feet paler.

It was taken very abundantly during summer about the mouth of the Canton River, in brackish water, and sometimes as far up as the city of Canton. It was usually found swimming at the surface, but sometimes on the muddy banks above low-water mark.

Specimens were also found among floating wood in Gaspar Strait by Captain Rodgers, then in the steamer "Hancock."

Genus ERIOCHIRUS De Haan

206. ERIOCHIRUS JAPONICUS[1] De Haan

Eriocheir japonicus DE HAAN, Fauna Japonica, Crust., 59, pl. XVII.

Eriochirus japonicus MILNE EDWARDS, Mélanges Carcinologiques, p. 142

In life the color is above very dark brownish-gray, closely punctate; below white, or cream-colored.

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[1] *Eriocheir japonicus* de Haan.

It was taken in the seine on sandy shores near the mouths of streams in the Bay of Hakodadi, Island of Jesso.

207. ERIOCHIRUS RECTUS[1] Stimpson

Eriochirus rectus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 103 [49], 1858.

Carapax depressed, broad posteriorly, narrowing anteriorly; length to greatest breadth as 1 : 1.06. Surface somewhat uneven, as in *E. japonicus,* but smooth and punctate. Pregastric lobules little salient. Front waved, indistinctly four-lobed; median sinus very shallow. Lateral margins nearly straight, converging; four teeth on each side, the posterior one rudimentary. Outer maxillipeds and pterygostomian regions pubescent. Chelipeds of moderate size; meros with granulated edges, the tooth near its summit very small; carpus with the encircling ridge of upper surface pubescent, and the tooth at the inner angle small; hand with a thick tuft of hair on outer surface; fingers strongly sulcated. The first three ambulatory feet are slender toward their extremities. The meros-joint of the ambulatory feet is ciliated above. The dactyli are shorter than in *E. japonicus* and less curved. Dimensions of the unique female specimen described: Length of carapax, 0.92; breadth, 0.975; length of third ambulatory foot, 2 inches.

It is allied to *E. japonicus,* but is more depressed, and easily distinguished by its straight converging sides and less distinctly lobed front.

Taken near Macao, China.

Genus HETEROGRAPSUS (Lucas) Milne Edwards

This genus was first proposed by Lucas in 1849, but has only recently been illustrated and placed on a firm basis by Milne Edwards, in his "Mélanges Carcinologiques." The genus *Hemigrapsus* of Dana is composed in part of *Heterograpsi,* but his *Hemigrapsus crassimanus* and *H. affinis* seem to us to belong more properly to *Cyrtograpsus* of the same author, a very distinct and well-marked genus (notwithstanding it is disregarded by Milne Edwards), forming a passage to the Varunaceæ. *Pseudograpsus nudus* and *P. oregonensis* of Dana will fall into this genus. In these crabs the meros of the outer maxillipeds is not auriculated, as in *Pseudograpsus* proper.

[1] *Eriocheir rectus* Stimpson.

208. HETEROGRAPSUS PENICILLATUS[1] (De Haan) Stimpson

Eriochcir penicillatus DE HAAN, Fauna Japonica, Crust., 60, pl. XI, fig. 6.
Heterograpsus penicillatus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 104 [50], 1858.

Distinguished from *H. crenulatus* and allied species by the lanosity of the hands; from *H. oregonensis* in its nearly straight and dilated front.

This species lives at and above low-water mark on sandy or muddy shores. It was found in great abundance in a muddy estuary at Simoda, Japan; also under stones on coarse sand in a bay on the coast of China, opposite Hongkong.

209. HETEROGRAPSUS OREGONENSIS[2] (Dana) Stimpson

Pseudograpsus oregonensis DANA, U. S. Expl. Exped., Crust., I, 334, pl. XX, fig. 6. STIMPSON, Crust. Pacific Coast N. Am., p. 28.

In this species the external side of the meros-joint of the outer maxillipeds is scarcely at all dilated, but other characters indicate a true affinity with *Heterograpsus.*

Found on sandy or muddy shores in sheltered bays, above low-water mark. Taken by us at San Francisco.

210. HETEROGRAPSUS SANGUINEUS[3] (De Haan) Milne Edwards

Grapsus sanguineus DE HAAN, Fauna Japonica, Crust., p. 58, pl. XVI, fig. 3.
Heterograpsus sanguineus MILNE EDWARDS, Mélanges Carcinologiques, p. 159.

Closely allied to *H. sexdentatus* and *H. nudus,* but differs from both in the smoothness of the infraorbital crest, which is only microscopically crenulated. It has no hairs or lanose spots on the hands.

A single specimen from China differs from North Japanese examples in its somewhat hairy feet, etc., and perhaps belongs to a distinct species. The coloration of this specimen is as follows: Above, dark porphyry purple, minutely mottled. A few small white spots on the feet. Below white, except the feet, which are pale purplish toward their extremities.

It was found among stones at low-water mark on the shores of a bay near Hongkong.

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[1] *Hemigrapsus penicillatus* (De Haan).
[2] *Hemigrapsus oregonensis* (Dana).
[3] *Hemigrapsus sanguineus* (De Haan).

Typical examples of the species were taken abundantly on the shores of the Straits of Sangar by Messrs. Brooks and Kern, and by the officers of the "Hancock."

211. HETEROGRAPSUS NUDUS[1] (Dana) Stimpson

Pseudograpsus nudus DANA, U. S. Expl. Exped., Crust., I, 335, pl. XX, fig. 7. STIMPSON, Pacific Coast N. A., Crust., p. 29.
Heterograpsus marmoratus MILNE EDWARDS, Mél. Carcin., p. 159.
Heterograpsus nudus STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 104 [50], 1858.

Found about the entrance of San Francisco Bay, among rocks and stones, not far below high-water mark.

Genus PSEUDOGRAPSUS Milne Edwards

212. PSEUDOGRAPSUS ALBUS Stimpson

Pseudograpsus albus STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 104 [50], 1858.

Small; carapax much flattened, smooth and glossy; proportion of length to breadth, 1 : 1.14. Epigastric lobules distinct. Posterior cardiac region defined. Front broad, depressed, nearly horizontal. Frontal margin thickened, straight or slightly convex, sufficiently projecting. Antero-lateral margin with two slight emarginations behind the angle of the orbit, indicating three minute teeth. External maxillipeds with the external angle of the meros-joint dilated and rounded. Chelipeds short, smooth, and glossy; inner angle of carpus prominent, acute; hand smooth on both sides, palm much shorter than the carpus; a tuft of short hair on the outside between the bases of the fingers. Ambulatory feet flattened, smooth, with neither granules nor spines on any part; penult and terminal joints somewhat hairy below; dactyli tapering, sulcated. Abdomen of the male rather narrow, tapering; penult joint subpentagonal, terminal joint oblong.

Color white, with a few scattered grayish dots and punctæ. Dimensions of a male: Length of carapax, 0.27; breadth, 0.282 inch.

Found under stones above low-water mark, on gravel, in a small harbor on the southern side of Kikaisima.

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[1] *Hemigrapsus nudus* (Dana)

Genus PLATYGRAPSUS[1] Stimpson

This name was proposed in the Proceedings of the Academy of Natural Sciences of Philadelphia for the genus called *Platynotus* by De Haan, this latter name having several times been previously used, and more than once for articulates.

213. PLATYGRAPSUS DEPRESSUS[2] (De Haan) Stimpson

Platynotus depressus DE HAAN, Fauna Japonica, Crust., 63, pl. VIII, fig. 2. MILNE EDWARDS, Mél. Carcin., p. 165.

Easily recognized by its flat, glossy carapax, which is of a brownish color, often variegated with yellowish white, purple, red, or black. The greatest breadth is at the second lateral tooth.

De Haan's figure of this species is poor, contrary to the usual accuracy seen in his work, and his description is defective in some points. The dactyli of the posterior pair of feet are not trigonal, but depressed and sulcated. The inner angle of the carpus is rounded only in very old specimens; in those of moderate size and in the young this angle forms a sharp tooth or short spine. Finally the species is not found "in fluviis montanis," but is a true marine form, living on gravelly shores above low-water mark.

It is the most common crab found on the shores of Japan, its geographical limits extending from 42° north latitude to the coast of China, in latitude 23° N. We took it at Hongkong, at Loo Choo, Ousima, and Kikaisima, at the Bonin Islands, Kagosima Bay, Simoda, the northeast coast of Niphon, and in Hakodadi Bay.

It seems to reach a larger size progressively as we go north, the largest being from Hakodadi, in one of which the carapax measures 1.02 inches in length and 1.23 inches in breadth. The Loo Choo specimens are remarkable in being of a deep purplish-red color, with feet tipped with orange, fingers tipped with white.

214. PLATYGRAPSUS CONVEXIUSCULUS[3] Stimpson

PLATE XVII, FIG. 3

Platygrapsus convexiusculus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 104 [50], 1858.

This species will be best described by a comparison with *P. depressus*, to which it is very closely allied. The carapax is broader and

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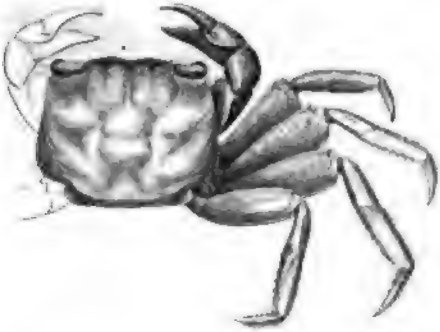
[1] *Gœtice* Gistel, Natur. Thierreichs, p. x, 1848, substituted for *Platynotus* de Haan, preoccupied.

[2] *Gœtice depressus* (De Haan).

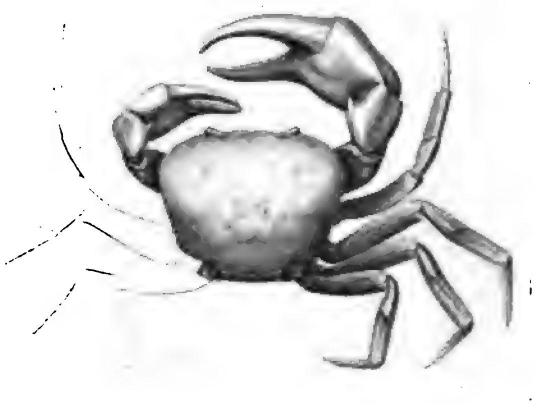
[3] *Gœtice convexiusculus* (Stimpson).



1

1a

1b



2

3

5a

4

5

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less depressed, the posterior portion being a little convex transversely. The surface is somewhat uneven, but smooth and glabrous. The gastric lobes are more prominent. Front broader, more inclined, and less projecting, with the median sinus broader and deeper. The second lateral tooth is sharp, more projecting, and more widely separated from the first or orbital angle. The infraorbital margin is more coarsely crenated. In other respects it is like *P. depressus*. Dimensions of a male: Length of carapax, 0.42; breadth, 0.51 inch. Proportion, 1 : 1.21.

Found at Loo Choo.

Genus PTYCHOGNATHUS Stimpson

Carapax flat above; antero-lateral margins acute, emarginated. Buccal area and maxillipeds very broad, but narrowed posteriorly. Exognath of outer maxillipeds greatly developed, as broad as the ischium of the endognath. No piliferous crest on the endognath; commissure of ischium and meros transverse; meros not as long, but twice as broad as the ischium, and very strongly auriculated at the antero-external angle, the auricle being nearly as large as the main body of the joint. Feet as in *Pseudograpsus*, etc.; hand not piliferous. Last joint of the sternum considerably exposed on either side of the abdomen. Abdomen of the male rather narrow. Terminal joint of female abdomen free.

This genus is founded on a single species from the eastern seas, which is remarkable for the flatness of its dorsal surface. It is allied to *Pseudograpsus* and to *Platygrapsus*, but sufficiently distinct from both in the character of its outer maxillipeds, from the former by the great breadth of these members, and from the latter by the transverse commissure of the endognath.

215. PTYCHOGNATHUS GLABER Stimpson

PLATE XVII, FIG. 5, 5*a*

Ptychognathus glaber STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 104 [50], 1858.

Carapax perfectly flat above, not at all deflexed anteriorly, and very little sloped at the postero-lateral margins. Proportion of length to breadth, 1 : 1.21. The H-shaped suture at the middle is deeply impressed. Gastric lobules obsolete. Surface smooth, punctate. Front broad, margin waved and grooved. Antero-lateral margin bidentate, there being one slight emargination behind the

angle of the orbit. The external suborbital lobe is obsolete. Infra-orbital crest inconspicuously crenulated. In the outer maxillipeds the exognath is always smooth; the endognath sometimes pubescent. Chelipeds large, smooth; meros with ciliated margins; carpus obtuse within; hand broad, little convex, smooth within; fingers somewhat gaping, denticulated within. Ambulatory feet sparsely hairy, to-mentose toward their extremities; dactyli robust, sulcated. Color dark yellowish brown, often covered with a blackish incrustation. Dimensions of a male: Length of carapax, 0.56; breadth, 0.68 inch.

This species lives in holes in gravelly mud, along the shores of ponds of brackish water, at the mouths of streams. Found in Port Lloyd, Bonin Island.

Genus ACMÆOPLEURA Stimpson

In the characters of the orbits, antennæ, abdomen, etc., this genus agrees with *Cyclograpsus*—at least with that section of it in which the orbits are nearly complete below. The lateral margins of the carapax are entire. The outer maxillipeds, however, nearly resemble those of *Heterograpsus*, being destitute of an oblique piliferous crest; their sides are straight; the meros-joint is square, equaling the ischium in length, and marked on its surface with a somewhat oblique sulcus which is not continued on to the ischium; the palpus is prosarthroid, and finally the exognath is narrow. The hands are lanose at or between the bases of the fingers.

This genus, being founded upon a single small specimen, needs further illustration. The characters above mentioned forbid its being included in any genus previously described.

216. ACMÆOPLEURA PARVULA Stimpson

PLATE XI, FIG. 4

Acmæopleura parvula STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 105 [51], 1858.

Carapax flat, broadest at the antero-lateral angles. Length to breadth as 1 : 1.105. Surface smooth, except anteriorly, where it is minutely rugate and moderately curving downward. Median gastric sulcus distinct. Front rather prominent, its margin somewhat convex. Antero-lateral margin acute. Infraorbital crest broadly 3- or 4-lobed; lobes smooth. Chelipeds equal, smooth externally; hand with three or four strong granules at the middle of the inner surface and a lanose surface externally between the bases of the

fingers. Ambulatory feet slender, setose; setæ very short, arranged on the superior longitudinal crests, there being one of these on the meros and two or three on the next three joints; a few long fine hairs below. Abdomen of the male tapering; penult joint pentagonal.

Color in life above light opaque red, brightest on the chelipeds. The surface is clean and shining. Dimensions of the carapax in the male: Length, 0.19; breadth, 0.21 inch.

Found under stones among pebbles in the third subregion of the littoral zone, on ocean shores at the Island of Ousima.

Genus CYCLOGRAPSUS Milne Edwards

217. CYCLOGRAPSUS LONGIPES Stimpson

Cyclograpsus longipes Stimpson, Proc. Acad. Nat. Sci. Phila., x, p. 105 [51], 1858.

Carapax subtrapezoidal; much narrowed anteriorly, and much flattened above. Length to posterior breadth as 1 : 1.21. Surface smooth and glabrous except toward the margins and frontal region, where it is minutely rugate transversely. Epigastric lobules distinct, though not prominent. On the antero-lateral margins there are often obscure indications of two or three obsolete teeth. Orbits nearly complete below, as in *C. integer*. Infraorbital crest 3- or 4-lobed externally. Oblique crest of outer maxillipeds on the ischium-joint passing almost longitudinally close to the margin. Chelipeds short; hand inflated, smooth within and without. Ambulatory feet very slender, more than twice as long as the carapax; meros minutely rugulose transversely; penult joint and dactylus setose; dactylus long, cylindrical, not tapering, and sulcated. Abdomen of the male rather narrow, somewhat tapering, but less so than in *C. punctatus;* last joint much narrower than the penult. The form of the abdomen is between that of *C. cinereus* and *C. punctatus.* It is in life fawn-colored above, darker anteriorly; below much paler; abdomen whitish. Eyes of a dark mahogany color. Dimensions of a male: Length of carapax, 0.28; breadth, posteriorly, 0.34; length of second pair of ambulatory feet, 0.63 inch.

Found under stones at the depth of one fathom, on coral gravel, in Port Lloyd, Bonin Islands.

218. CYCLOGRAPSUS PUNCTATUS Milne Edwards

Cyclograpsus punctatus MILNE EDWARDS, Hist. Nat. des Crust., II, 78; Mél. Carcin., p. 163.
Gnathochasmus barbatus McLEAY, in Smith's Illust. Zoöl. S. Africa, Crust., pl. III.

Living specimens are of a purplish-brown color, with black punctæ.

It lives among rocks and stones on sandy shores, in the third subregion of the littoral zone. Found at Simon's Bay, Cape of Good Hope; also in the harbor of Hongkong, China.

219. CYCLOGRAPSUS AUDOUINI Milne Edwards

Cyclograpsus audouini MILNE EDWARDS, Hist. Nat. des Crust., II, 78; Mél. Carcin., p. 163.

Our specimens belong in all probability to the species here quoted, but the distinctions of species in this genus are so slight that it may well be different. The dactyli of the walking feet are much thicker than in the specimens referred to *C. audouini* by Dana.

The color in life was red, much darker on the anterior part of the carapax; in some specimens there were minute white markings. Hands paler; feet rather dark above. Below, body and members white. The dimensions of the largest specimen, a male, are: Length of carapax, 0.88; breadth, 1.09 inches.

It is common under stones above half-tide mark in Port Jackson or Sydney Harbor, Australia.

Genus CHASMAGNATHUS De Haan

The genus *Chasmagnathus* is very closely allied to *Helice*, and we can see no sufficient reason for placing these genera in separate families, as is done by Milne Edwards in his "Mélanges Carcinologiques." The arcuated sides of *Chasmagnathus* is almost the only character in which it resembles the Cyclograpsaceæ. The jugal regions are as distinctly reticulated as in *Sesarma;* the front, orbits, antennæ, etc., are as in *Helice*, and the outer maxillipeds only differ from those of the latter genus in being more elongated.

The species described by Dana are intermediate between *Chasmagnathus* and *Helice*, and some of them seem to belong properly to the latter genus.

220. CHASMAGNATHUS CONVEXUS De Haan

Chasmagnathus convexus DE HAAN, Fauna Japonica, Crust., p. 56, pl. VII, fig. 5. MILNE EDWARDS, Mélanges Carcinologiques, p. 166.

Our specimen is a male, a little smaller than that figured by De Haan. In this the lateral margins are sufficiently arcuated and their notches rather broad. The granules of the surface are smaller.

It was taken in the paddy fields, which are more or less covered with fresh water, at Loo Choo.

Genus HELICE De Haan

221. HELICE TRIDENS De Haan

Helice tridens DE HAAN, Fauna Japonica, Crust., p. 57, pl. XI, fig. 2, and XV, fig. 6. MILNE EDWARDS, Mél. Carcin., p. 155.

Taken on the shores of a muddy estuary at Simoda, Japan; also at Ousima and Loo Choo.

Genus SESARMA Say

222. SESARMA INTERMEDIA (De Haan) Milne Edwards

Pachysoma intermedium DE HAAN, Fauna Japonica, Crust., p. 61, pl. XVI, fig. 5.
Sesarma intermedia MILNE EDWARDS, Mél. Carcin., p. 152.

The specimens which are here referred to *S. intermedia* are somewhat broader than those of the species figured by De Haan, and the hand is more rugose above. With the exception of the marginal tooth behind the orbital angle, they resemble in nearly every respect *S. dehaani*, of which this is possibly a variety.

The color in life was yellowish-gray, mottled with brownish. Hands white.

Found in paddy fields and in mud along fresh water ditches on the shores of the island of Ousima; also taken at Simoda and at Hongkong.

223. SESARMA SINENSIS Milne Edwards

Sesarma sinensis MILNE EDWARDS, Mélanges Carcinologiques, p. 152.

This species is briefly described by Milne Edwards as follows: "Carapace presque carrée et faiblement sillonnée. Mains arrondies en dessus et verruqueuses, mais sans crêtes pectinées. Pattes grêles,

à dactylopodites très allongés, comprimés et épineux.—Mers de Chine."

Our crab agrees pretty well with this description. The hand is, however, rather tuberculated than verrucose, and the armature of the dactyli consists rather of very stiff setæ than spines, as they are flexible, and jet black in color.

The carapax is considerably flattened above, and less uneven than is usual. The anterior margins of the epigastric lobules are in the same straight line. The feet are slender, with narrow meros-joints. Color yellowish brown, mottled.

Found on marshy shores in the harbor of Hongkong, China.

224. SESARMA BIDENS (De Haan) Dana

Pachysoma bidens DE HAAN, Fauna Jap., Crust., p. 60, pl. XVI, fig. 4, and XI, fig. 4.
Sesarma bidens DANA, U. S. Expl. Exped., Crust., I, 353. MILNE EDWARDS, Mél. Carcin., p. 151.

Inhabits muddy estuaries. Taken at Simoda and at Hongkong. From the former locality we have but one specimen, a female, in which the oblique superior crests of the hand are scarcely pectinated, and there are only small tubercles on the superior edge of the movable finger.

The Hongkong specimens agree in every respect with De Haan's species except that the meros-joints of the walking feet are somewhat less dilated and the carapax less abundantly setose anteriorly.

225. SESARMA DEHAANI Milne Edwards

Pachysoma quadratum DE HAAN, Fauna Jap., Crust., p. 62, pl. VIII, fig. 3.
Sesarma dehaani MILNE EDWARDS, Mél. Carcin., p. 150.

Color in life yellowish, clouded with black anteriorly and with olive posteriorly. Beneath yellowish-green; meros of chelipeds reddish. Hands lemon colored. In specimens from Whampoa the hands were white externally and the eyes bright yellow. The carapax is sometimes bright purplish anteriorly.

Of this species the largest and finest specimens (in some of which the carapax measured 1.83 inches in length and 1.95 inches in breadth) were found at Port Lloyd, Bonin Islands, where they live in holes in the banks of fresh-water streams near their embouchure. It is a very courageous animal, defending itself successfully from the attacks of small dogs. It also occurred in brackish water at Whampoa, China, and at Simoda, in Japan.

226. SESARMA PICTA (De Haan) Milne Edwards

Pachysoma pictum DE HAAN, Fauna Jap., Crust., p. 61, pl. XVI, fig. 6.
Sesarma picta MILNE EDWARDS, Mél. Carcin., p. 150.

Found at Ousima.

227. SESARMA RUPICOLA Stimpson

PLATE XVII, FIG. 1, 1*a*, 1*b*

Sesarma rupicola STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 106 [52], 1858.

Carapax depressed, quadrate, much broader than long; proportion of length to breadth, 1 : 1.19. Surface very uneven, anteriorly transversely rugulose. Anterior gastric lobules well marked; those of the middle pair with oval spaces at the summits, as if eroded. Frontal region somewhat minutely tuberculated; frontal margin waved. Lateral margins straight, entire, but sometimes with obscure indications of two or three teeth, best seen in a side view. Epistome partly granulated. Chelipeds (of female) of moderate size; inner edge of meros crenulated as far as the triangular tooth at the apex, anterior edge nearly smooth; surface of carpus with short granulated rugæ. Hand on the outer surface smooth toward the extremities, but granulated above and posteriorly; granules small, those of the superior surface arranged in three or four oblique but nearly longitudinal rows, not parallel; a small, sharp, denticulated tooth on the upper edge of the hand at the base of the dactylus; inner surface granulated, granules scattered; dactylus ornamented above with two or three longitudinal rows of very small tubercles. Ambulatory feet rather long; meros only moderately dilated; last two joints moderately provided with short, stiff hairs.

In life carapax black, with a few small bluish-white blotches; feet pale grayish, mottled. Below bluish-grey. Fingers and lower surface of the hand pale reddish-white. Dimensions of the female: Length of carapax, 0.78; breadth, 0.92 inch.

It is closely allied to *S. affinis*, but differs from this as well as from *S. quadrata* in its less dilated meros-joints, from *S. picta* in its less oblique and non-pectinated crests of the hand and non-plicated finger. There is also no tuberculated ridge on the inner surface of the hand.

This species differs in its habits from most of the genus *Sesarma*. It lives among rocks at about half-tide, on shores more or less exposed to the surf. Found in Fou-kow Bay, in the island of Ousima.

228. SESARMA ANGUSTIPES Dana

Sesarma angustipes DANA, U. S. Expl. Exped., Crust., I, 353, pl. XXII, fig. 7.

Found at Greytown or San Juan, on the eastern coast of Central America, by Mr. Charles Wright, botanist of the expedition.

229. SESARMA VESTITA Stimpson

PLATE XIII, FIG. 6

Sesarma vestita STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 106 [52], 1858.

In this species the form is depressed, and the body and feet are covered above with setæ or hairs, irregular in length, but short, entangling sordes, and mostly arranged in transverse lines. Carapax quadrate, broadest anteriorly, at the sharp orbital angles, which project considerably. Proportion of length to breadth, 1 : 1.03. Surface uneven, with smooth, low prominences. Sides in a vertical sense rounded, except just behind the orbital angle; the line separating the dorsum from the reticulated latero-inferior regions is, however, distinctly raised. There are no lateral teeth behind the orbital angle. Anterior gastric lobules convex, smooth, the middle ones much the largest. Frontal region short, uneven, glossy; the margin waved. Outer maxillipeds small. Chelipeds small, even in the male; inner edge of meros smooth, but with the projecting angle near its inner extremity slightly denticulated; carpus nearly smooth; hand with two or three slight, nearly transverse superior crests, that near the base of the dactylus longest and most prominent; fingers externally smooth; dactylus with acute superior edge. Ambulatory feet moderately long; meros large, much dilated, with subscabrous surface, its extero-inferior angle rounded and denticulated, the other joints toward extremity slender; dactyli very slender, smooth, with sharp, much-curved tips.

Color in life greenish-gray, mottled; feet somewhat annulated. Dimensions of a female: Length of carapax, 0.29; breadth, 0.3 inch.

Found under stones on a gravelly beach in a small harbor of Kikaisima; also at Ousima.

Genus HOLOMETOPUS Milne Edwards

230. HOLOMETOPUS HÆMATOCHEIR[1] (De Haan) Milne Edwards

Pachysoma hæmatocheir DE HAAN, Fauna Jap., Crust., p. 67, pl. VII, fig. 4.
Holometopus hæmatocheir MILNE EDWARDS, Mél. Carcin., p. 154.

The post-frontal ridge, although straight, is always separated into four divisions by slight emarginations, indicating the normal protogastric lobules.

Found on the shores of a muddy estuary at Simoda; also at Ousima and at Hongkong.

CAMPTANDRIIDÆ

Genus CAMPTANDRIUM Stimpson

Carapax subhexagonal, facial region in breadth equalling two-thirds that of the carapax, front scarcely exceeding in extent a fourth part of the width of the carapax; its margin strongly waved in the perpendicular plane, but nearly straight when seen from above. Antero-lateral margin oblique, straight or slightly concave, armed with three small somewhat distant teeth, the third or lateral tooth prominent, and projecting directly outward. Postero-lateral margin convex. Posterior margin about equal in length to the anterior margin or width of facial region. Upper surface unequal, with three or four interrupted transverse ridges, which are very prominent and somewhat pubescent in the male, but much less distinct in the female; gastric region small; the anterior median lobules sufficiently prominent; hepatic regions large; genital and cardiac regions very broad. Eyes of moderate length; orbits transverse, with large infero-exterior sinus; internal suborbital lobe small, dentiform, not joining the front; inferior margin of orbit and infraorbital crest approximated, and not produced exteriorly beyond the outer angle of the orbit. Antennulæ oblique, in deep fossettes. Antennæ short; the basal joint small, rounded; third joint lying in the internal hiatus of the orbit. Epistome of moderate extent. Latero-inferior regions smooth. Anterior margin of buccal area deeply waved in the vertical plane; median septum strongly prominent. Palate abbreviated, smooth. External maxillipeds rather short and broad, smooth, squarish, not gaping; exognath palpigerous, but not bearing a tooth

[1] *Sesarma hæmatocheir* (De Haan).

on its inner margin, slender and half concealed beneath the endognath, the portion next the ischium only being exposed to view; endognath broad, ischium quadrate; meros-joint equaling the ischium in length and much broader than long, broadly auriculated at the external angle, the auricle protruding forward and not sideways; palp prosarthroid, inserted at the bottom of the sinus in the anterior side of the meros. Chelipeds rather small and weak, unarmed; those of the female with fingers resembling those of the female *Gelasimus*. Ambulatory feet slender, unarmed, smooth, pubescent near the base; meros-joint with a ridge on the posterior surface parallel with the superior margin; dactyli slender, obliquely compressed, shortly ciliated. Sternum broad; its posterior joint widely exposed on either side of the abdomen, its arcuated anterior margin next the mouth projecting, laminiform, like a septum, for the better separation of the mouth from the extremity of the abdomen. Abdomen of the male somewhat tapering, but not dilated at the base, strongly constricted or sinuated on each side at the middle; terminal joint not narrower at the base than the penultimate joint. The male abdominal appendages of the first pair are long, slender, bent or geniculated beyond the middle, where there is a strong tubercle or papilla on the convex side, and contorted toward their extremities; those of the second pair slender, minute. Abdomen of the female broad, covering the whole of the sternum with the exception of its postero-lateral corners; terminal joint broad and scarcely free, the sides of the penult joint being a little expanded so as to enclose its base in a shallow sinus.

This genus inhabits the Chinese seas.

In the form of the carapax approaches somewhat *Cyrtograpsus* Dana, but the characters of the male abdomen, length of eyes, etc., would remove it from the *Grapsidæ*.

231. CAMPTANDRIUM SEXDENTATUM Stimpson

PLATE XVII, FIG. 4

Camptandrium sexdentatum STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 107 [53], 1858.

The trivial characters of this species may be gathered mostly from the generic description preceding. Reprehensible as the practice which we now follow may be in general, it was thought advisable in the present case, where the characters of the animal exclude it from all known families, by which their generic or specific value might be determined. We have therefore given under the head of the genus

as complete a general description of the crab as the number and nature of our specimens would admit. Of these there are five, only one of which is a male, and that a young individual. From the largest of the females the following measurements were taken: Length of carapax, 0.265; breadth, 0.32 inch. Proportion, 1 : 1.21. The color in life was brownish-gray

They were dredged from a muddy bottom at the depth of six fathoms, in bays of the coast near Hongkong, China.

ASTHENOGNATHIDÆ

Genus ASTHENOGNATHUS Stimpson

This genus is described from a female specimen, the only one which we were fortunate enough to discover. In the form of the carapax and the relative size of the feet it has considerable resemblance to *Pinnixa*. The carapax is transverse, very broad posteriorly, subtruncate anteriorly, with the antero-lateral angles, however, obtuse. The margins are entire. Surface very smooth and even, but seen under the lens to be granulated. The facial region occupies half the width of the carapax. Front deflexed, of moderate extent. Eyes small, movable, with thick peduncles; orbits not very deep. Internal suborbital lobe almost obsolete. Infraorbital crest sufficiently remote from the suborbital margin, prominent and smooth. Antennulæ transverse, situated in deep fossettes. Antennæ sufficiently long, very slender, traversing the inner hiatus of the orbit. Epistome of moderate extent. Palate smooth, with no median septum. Buccal area of moderate size, arcuated in front. External maxillipeds slender and weak, gaping so much as to be considerably remote from each other, with not even the palpi in contact; exognath exposed; ischium of the endognath larger than the meros; meros subquadrate, lightly grooved or excavated on outer surface; palpus exarthroid rather than prosarthroid; dactylus minute, ciliated. Chelipeds small, meros with a setigerous protuberance on the middle of its upper edge; hand moderately compressed, slender, acute above, margined below with a crest; fingers acute, compressed, sulcated, a little longer than the palm, their inner edges scarcely toothed. Ambulatory feet of the second and third pairs very thick, as in *Pinnixa;* those of the fourth pair slender, scarcely overreaching the meros-joint of the preceding pair. Sternum broad, covered by the female abdomen except at the margins and the postero-lateral angles. Terminal joint of the abdomen small rhomboidal.

232. ASTHENOGNATHUS INÆQUIPES Stimpson

PLATE XIV, FIG. 1

Asthenognathus inæquipes STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 107 [53], 1858.

The remarks under the head of *Camptandrium sexdentatum* will apply with equal justice to this species.

The specimen is lead colored. Its dimensions are: Length of carapax, 0.29; breadth, 0.375 inch. Proportion, 1 : 1.28.

It was dredged from a sandy-mud bottom in thirty fathoms, off the east coast of Niphon, in latitude 38° N.

XENOPHTHALMIDÆ

Genus XENOPHTHALMUS White

This genus is very imperfectly described by White, like many others instituted by him. We give below a few of its more important characters, by which it will be seen that it is not properly included in the Pinnotheridæ, but is the type of a new family. The equality in size between the meros and ischium-joints of the outer maxillipeds is a prominent distinctive feature, since the most important family character of the Pinnotheridæ is the rudimentary state of the ischium. Milne Edwards, in including the genus in that family ("Mélanges Carcinologiques," p. 186), was probably guided only by the figure and descriptions of White.

The carapax is notched at the margin on each side, as if constricted. Antennulæ minute; fossettes very shallow, or none. Antennæ robust. Eyes minute, movable, placed longitudinally in deep chinks, and apparently destitute of black pigment. We have failed to observe the "cylindrical tooth" spoken of by White. As in *Hymenosoma,* there is no distinct epistome. In the outer maxillipeds the ischium equals the meros in size; the palpus is spirally twisted; dactylus in form resembling that of *Pinnotheres.* The chelipeds are very small, even in the male. The anterior margin of the sternum projects in the form of a thin laminiform crest, and is separated from the adjacent parts—bases of the maxillipeds and feet, etc.—by a very deep chink or fissure. The verges are sternal. The male abdomen is oblong, not dilated at the base, but of nearly the same breadth throughout; a slight contraction at the fifth joint; extremity obtuse, reaching quite to the anterior margin of the sternum.

233. XENOPHTHALMUS PINNOTHEROIDES White

Xenophthalmus pinnotheroides WHITE, Ann. and Mag. Nat. Hist., XVIII, 177; Voy. Samarang, Crust., p. 63, pl. XII, fig. 3. MILNE EDWARDS, Mél. Carcin., p. 187.

Our specimen was dredged in the harbor of Hongkong from a muddy bottom, in six fathoms.

PINNOTHERIDÆ

Genus PINNOTHERES Latreille

234. PINNOTHERES OBSCURUS Stimpson

Pinnotheres obscurus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 108 [54], 1858.

The only specimen in our possession is a female, of which the following is a description: Carapax broad, inclining to subtrapezoidal in form, but rounded at the angles and more or less convex on every side. Proportion of length to greatest breadth, 1 : 1.36. Surface naked, glossy. Hepatic regions forming rather prominent corners to the carapax; their upper surface depressed. Front very slightly projecting beyond the antero-lateral angles, and much deflexed, truncated below with a nearly straight margin. Outer maxillipeds large, meros curved, very oblique, with smooth and glossy surface, and the margin somewhat hairy at the anterior half of the inner side; palpus very small, hairy, not reaching beyond the inner angle of the meros; carpal joint thick; dactylus slender, subcylindrical, attached to the penult-joint rather beyond the middle and projecting beyond its extremity. Ambulatory feet nearly equal in length, those of the last two pairs a little longer; dactyli of the first two pairs short; that of the third pair long, curved inward; that of the last pair nearly as long as the penult joint, and very slender, nearly straight, tapering, styliform, with hairy margin.

Color dark brown. Length of the carapax, 0.33; breadth, 0.45 inch.

Found at Hongkong.

235. PINNOTHERES BONINENSIS Stimpson

Pinnotheres boninensis STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 108 [54], 1858.

Description of a female. Carapax rather broad, truncate before. Proportion of length to breadth, 1 : 1.25. Surface naked. Front

not protruded. Outer maxillipeds pilose, hairs plumose; palpus short; penult joint with extremity almost pointed; dactylus minute, joined at about the middle of the penult joint. Ambulatory feet of the third pair longest; dactyli of the first and second pairs short, equal; those of the third pair very long and tapering to a fine point; those of the last pair also long. Dimensions of the carapax: Length, 0.168; breadth, 0.211 inch.

Found in small oysters from the rocks at the Bonin Islands.

236. PINNOTHERES PARVULUS Stimpson

Pinnotheres parvulus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 108 [54], 1858.

Description of the female: Carapax narrower than in *P. pisum;* front nearly the same as in the female of that species. Outer maxillipeds rather hairy; exognath, excluding its palp, a little less than half as long as the meros-joint of the endognath; penult joint of endognath twice as long as carpus; dactylus slender, reaching to the extremity of the penult joint. Ambulatory feet toward extremities hairy; those of the last two pairs longer than the first two, and with proportionally longer dactyli. Length of the carapax, 0.14 inch.

A specimen of this species was found in each and every example of the small bivalve *Meroë quadrata,* of which several were dredged from a sandy bottom in twenty-six fathoms, in the China Sea, at about latitude 23° N.

Genus PINNIXA White

The best known species of this very distinct genus are natives of the American coast, but they will undoubtedly be found to be numerous at the proper latitudes in all parts of the globe, when sought for in their peculiar lurking places. They are parasitic in their habits, like the *Pinnotheres,* which they so much resemble in the structure of their jaw-feet; but in place of living with the bivalve mollusk in his shell, they prefer the society of marine worms and worm-like Holothuridæ, in the tubes or holes of which they are generally found. In their transversely elongated shape they are well adapted for slipping about in such cavities. One South Carolinian species lives in the tubes of *Chætopterus,* another in the hole of the large *Arenicola,* and the larger of the expedition species was found in the hole of a *Caudina.*

The *Pinnothera faba* of Dana is intermediate in its characters between *Pinnotheres* and *Pinnixa,* but has the maxillipeds of the

latter genus. Its habits, when observed, will throw much light upon its affinities.

The species of this genus, as far as known, differ from each other by strongly marked characters.

237. PINNIXA TUMIDA Stimpson

Pinnixa tumida STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 108 [54], 1858.

Of this species three examples are found among our collections, all females, to which the following description will apply: The body is transversely cylindrical, and very much swollen. The greatest breadth of the carapax is at the bases of the third pair of ambulatory feet. Length to breadth as 1 : 1.83. Surface smooth. There is no antero-lateral crest and no transverse ridge posteriorly, as are seen in most species. The median depression is shallow. Front narrow. Outer maxillipeds closely fitting to each other and to the margin of the buccal area; palpus large; dactylus attached near the base of the penult joint, overreaching it but little at the extremity, and, like that joint, provided with a long pencil of hairs. Chelipeds moderately large; meros and carpus-joints thickly hairy within; hand externally smooth; fingers gaping; dactylus oblique, with a tooth at the middle; immovable finger, with minutely serrated inner margin and a subterminal tooth forming a notch for the reception of the tip of the dactylus. Ambulatory feet hairy, those of the third pair longest; those of the first and second pairs slender; last two pairs stout and thick; dactyli slender, with five or six longitudinal carinæ. Female abdomen convex, covering the whole of the sternum with the exception of its posterior corners; surface along the middle most prominent.

Color in life: Above blackish, with a few bluish-white spots posteriorly and at the sides; below bluish-white, often inclining to a darker hue, like "neutral tint." Dimensions of the carapax: Length, 0.3; breadth, 0.55 inch.

Found in the holes of *Caudina* (a Holothurian) on sandy beaches in the fourth or lowest subregion of the littoral zone, in the Bay of Hakodadi, Japan.

238. PINNIXA PENULTIPEDALIS Stimpson

Pinnixa penultipedalis STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 108 [54], 1858.

Description of the single female specimen: Body rather depressed, and very broad; proportion of length to breadth, 1 : 2.11. Carapax

with a transverse ridge near the posterior extremity, smoothly rounded, and but little elevated, traversing the whole breadth of the carapax. Surface smooth and glossy. Front not deflexed. Chelipeds hairy; hand small, slender, tapering toward the straight, slender fingers, which are not gaping and not at all deflexed. Ambulatory feet of the second pair scarcely larger than the first pair; the meros-joint hairy, remaining joints toward extremities smooth and naked. The feet of the penultimate pair are very large and thick, smooth; meros four-fifths as broad as long, its superior edge somewhat acute, indistinctly granulated toward the base, its infero-posterior surface minutely granulated. Last pair of feet small, ciliated. The surface of the sides of the carapax or antero-inferior regions and around the bases of the feet is hairy. There is a transverse, ciliated line across the abdomen at its second joint, extending between the bases of the penultimate pair of feet. In life the carapax is dark gray, mottled with black. Its dimensions are: Length, 0.132; breadth, 0.28 inch.

Found among dead shells on a muddy bottom in ten fathoms, in the harbor of Hongkong, China.

HYMENOSOMIDÆ

Genus HYMENOSOMA Leach

239. HYMENOSOMA ORBICULARE Leach

Hymenosoma orbiculare LEACH, DESMAREST, Consid. sur les Crust., p. 163, pl. XXVI, fig. 1. MILNE EDWARDS, Hist. Nat. des Crust., II, p. 36, pl. XIV bis, fig. 13; Illust. Cuv. R. A., pl. XXXV, fig. 1; Mél. Carcin., p. 188.

The published figures of this species must in many respects be imperfect, as they show great discrepancies.

Found at the Cape of Good Hope, in False Bay, on sandy bottoms, in ten fathoms.

240. HYMENOSOMA GEOMETRICUM Stimpson

Hymenosoma geometricum STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 108 [54], 1858.

The only specimen before us is a male, in which the breadth, measured at the bases of the first pair of ambulatory feet, is exactly equal to the length of the carapax. The body is much flattened above and below. The carapax is indurated, and everywhere uniformly granulated above. Dorsal area broadly ovate, encircled by an elevated, granulated ridge, and divided into ten areolets by nar-

row linear sulci, somewhat as in Desmarest's figure of *H. orbiculare* (Consid. sur les Crust., pl. XXVI, fig. 1). The anterior three areolets are very large, and occupy most of the surface; postmedian areolet protuberant at its middle; posterior two areolets very small, much broader than long. The hepatic areolets are also small. Rostrum slender, elongate-triangular, pointing obliquely upward at an angle of 45°. There is a small elevated præorbital tooth on either side at the base of the rostrum. The two teeth at the infero-exterior angle of the orbit are sharp, and there is a small but prominent lateral tooth or spine on the surface of the hepatic region behind the orbit, behind which there is a smooth excavation, and behind this again a granulated protuberance. Posteriorly the inferior margin of the carapax forms two prominent projections or teeth, the base of the abdomen lying in the sinus between them. The outer maxillipeds are very slender, with the ischium-joint nearly as long as the meros and not as broad. Chelipeds clavate, granulated above like the carapax; hand short, with inflated, subglobose palm, which is smooth and glabrous exteriorly; fingers short; dactylus one-toothed near the middle within. Ambulatory feet very long and slender, those of the second pair twice as long as the carapax. The feet are sparsely provided with fine, inconspicuous hairs. The dactyli are very slender, not flattened, and taper to a fine, almost hair-like extremity.

The color in life is reddish. Dimensions of the male: Length of carapax, 0.318; breadth at bases of first pair of ambulatory feet, 0.318; greatest breadth of dorsal area, 0.24; length of ambulatory feet of second pair, 0.66 inch.

This species is certainly distinct from *H. orbiculare,* if the published figures and descriptions of that species are to be relied upon. Besides less important characters, the sharp lateral teeth on the hepatic region and the slenderness of the ischium-joint of the outer maxillipeds will be sufficient to distinguish it. Unfortunately we have no specimens of the true *H. orbiculare* upon which to found a comparison, as the examples which were taken at the Cape, and identified with that species at the time, were all lost by accident.

Our specimen was dredged from a sandy bottom in twelve fathoms, in Simons Bay, Cape of Good Hope.

Genus HALICARCINUS White

The epistome in this genus is sufficiently well defined. The new species discovered by us seems to form a passage to *Elamene*, from which *Halicarcinus* would seem to be best distinguished by the want

of a septum between the antennulæ and the equality in size of the meros and ischium-joints of the outer maxillipeds. The orbits appear nearly the same in both. Characters derived from the orbits and eyes (as "retractile" and "non-retractile") are as difficult of apprehension here as among some Maioids.

241. HALICARCINUS OVATUS Stimpson

Halicarcinus ovatus Stimpson, Proc. Acad. Nat Sci. Phila., x, p. 109 [55], 1858.

Carapax subovate, narrowing before. Length and breadth nearly equal. Upper surface smooth, flattened in the male, somewhat convex in the female. Regions generally sufficiently distinct, separated by linear sulci. Lateral margins angular, with a small acute tooth at each angle, of which there are two on each side of the carapax. Front prominent, with three deeply cut, closely appressed, equal, flattened teeth projecting from beneath the straight supra-frontal margin, but nearly at the same level. Internal antennæ large. Epistome moderately large. Buccal area of moderate size, closed in front; maxillipeds somewhat convex or protuberant. Chelipeds of male subclavate, smooth, sparsely hairy within; meros with a small tooth at summit; hand with rounded, swollen palm and rather slender fingers minutely serrated within. Ambulatory feet long and slender, naked; a small, sharp tooth at the summit of the meros-joint. The feet of the middle pairs are a little more than twice as long as the carapax. Dactyli falciform, and slender from the base throughout. Abdomen of the male contracted near the extremity; terminal joint subcordate, obtuse. Dimensions of carapax in a male: Length, 0.251; breadth, 0.252 inch.

Taken in Port Jackson, Australia.

Genus TRIGONOPLAX Milne Edwards

242. TRIGONOPLAX TRUNCATA Stimpson

Trigonoplax truncata Stimpson, Proc. Acad. Nat. Sci. Phila., x. p. 109 [55], 1858.

Carapax not indurated, rounded-ovate, smooth, above flat or slightly concave in the male, slightly convex in the female. Proportion of length to breadth, 1 : 1.07. Regions scarcely distinct. Lateral margin with two or three equidistant inconspicuous angles, better marked in the female than in the male, but seldom dentigerous. Posterior margin straight or slightly convex. The sharp margins

of the carapax anteriorly and laterally project very considerably in a horizontal direction, concealing the eyes, antennæ, and bases of the feet. They project most anteriorly in the adult female. Front sufficiently prominent, broadly truncated; interantennulary septum strongly projecting. Antennulæ small. The inferior surface, against which the eyes rest, is considerably hollowed out for their reception. Buccal area small in the female. Outer maxillipeds nearly as in *T. unguiformis*. Chelipeds of the male long, smoothly rounded; meros slender; hand oblong, inflated; fingers somewhat excavated within throughout their length. Ambulatory feet slender, smooth, naked, a small spine at the superior extremity of the meros and carpus-joints; dactyli greatly compressed, strongly falciform, not tapering, but of equal breadth even to their tips. Abdomen of the male somewhat elongated, triangular, its extremity reaching nearer to the mouth than is the case in *T. unguiformis*.

Color in life dark purplish-red above, with four white spots on the carapax—two at the bases of the posterior pair of feet, and two smaller ones in front of them. Dimensions of a male: Length of carapax, 0.21; breadth, 0.225; length of cheliped, 0.4; of ambulatory foot of second pair, 0.56. In the female: Length of carapax, 0.298; breadth, 0.362 inch.

Found under stones at low-water mark, in weedy rock pools. Also dredged in eight fathoms, sandy bottom. It occurred at Ousima and among the reefs opposite Napa, Loo Choo.

Genus RHYNCHOPLAX Stimpson

This genus resembles *Trigonoplax* in form. The body is triangular, but less depressed, and longer than broad. Lateral margin bidentate. Rostrum arising from beneath the anterior margin of the dorsum, tridentate, the median tooth largest, elongated, bent upward; the lateral teeth minute and sharp. Antennulæ rather large, approximated, not separated by a septum. Eyes not retractile. Extraorbital spine small. Subhepatic region prominent, with somewhat acute summit. Epistome large. Ischium-joint of the external maxillipeds scarcely larger than the meros. Chelipeds of the male large and strong, scarcely shorter than the walking feet. Ambulatory feet of the first pair longest; dactyli of all falciform, much curved. Abdomen of the male oblong and lightly contracted toward the extremity.

This genus approaches still nearer to the Maioids than *Trigonoplax*, but, like that, is excluded from that division by its sternal verges.

243. RHYNCHOPLAX MESSOR Stimpson

Rhynchoplax messor STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 109 [55], 1858.

In this species the carapax is sufficiently indurated. The proportion of breadth to length in the male specimen described is 1 : 1.1. Carapax triangular, somewhat convex; surface smooth but uneven, with a few scattered setæ. Gastric and cardiac regions somewhat protuberant; branchial regions often depressed. Lateral teeth small but sharp and prominent. Median tooth of the rostrum flattened, spatuliform, equaling in length about one-fifth that of the carapax and pointing obliquely upward. Chelipeds claviform, sparsely setose; meros with four or five teeth on the superior edge; carpus with three or four small blunt teeth above; hand smoothly rounded, with one very small tooth on the middle of the upper side; inner surface about the bases of the fingers thickly lanose. Ambulatory feet slender, each joint dentigerous at the middle and at the outer extremity, with the exception of the dactyli which are of moderate length, and strongly sickle-shaped.

Color purplish-brown and yellowish, variegated. Dimensions of the carapax: Length, 0.241; breadth, 0.22; length of cheliped, 0.42; of first pair of ambulatory feet, 0.455 inch.

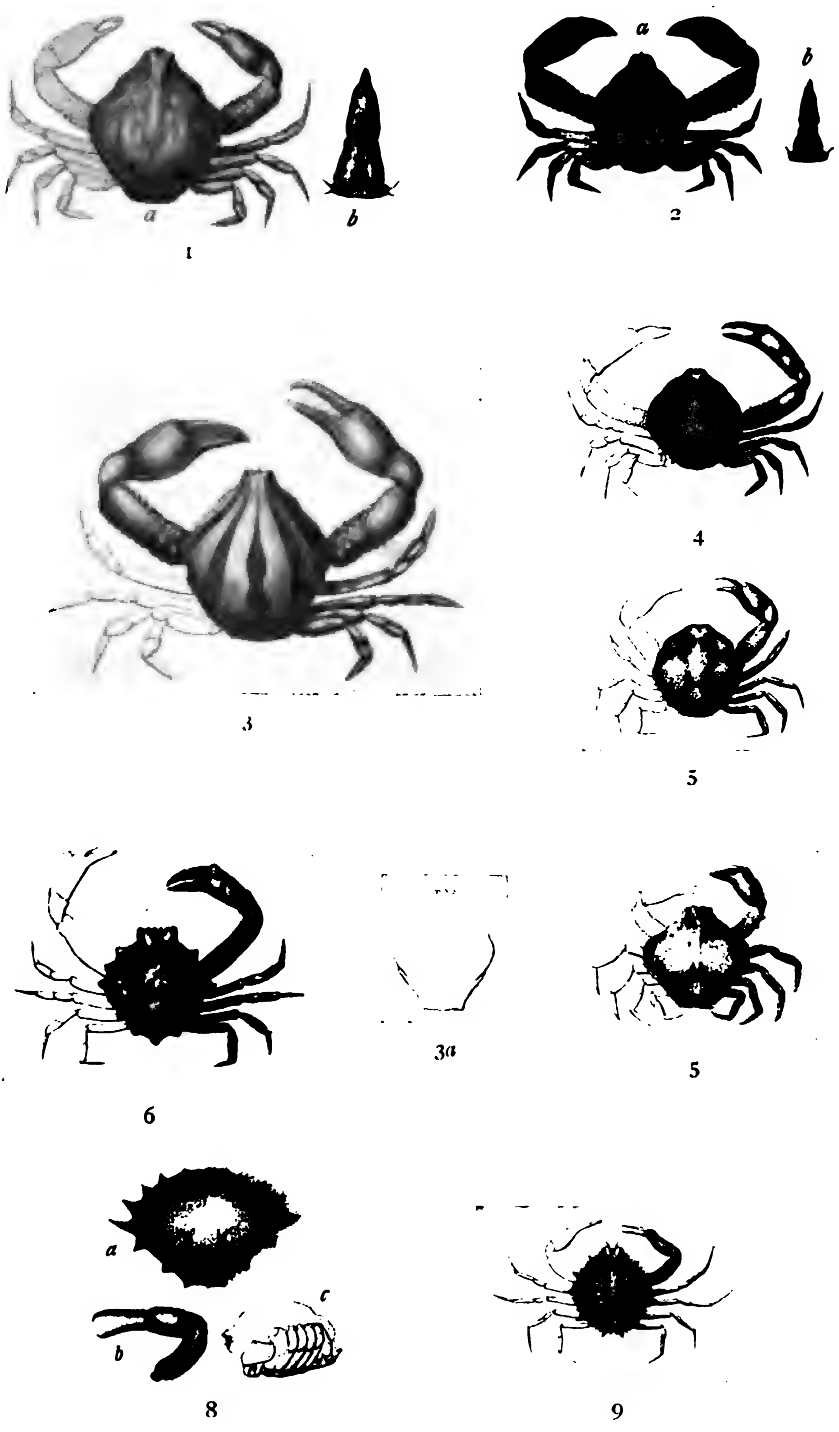
This crab, like all others of the family, dies when placed in spirits in such a state of brittle rigidity, with feet outstretched and easily separated, that it is almost impossible to preserve a perfect specimen.

It was taken at Simoda, at low-water mark.

244. RHYNCHOPLAX SETIROSTRIS Stimpson

Rhynchoplax setirostris STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 109 [55], 1858.

Description of a female: Carapax but little indurated, ovate, flattened; proportion of breadth to length, 1 : 1.08. Surface nearly smooth; sparsely and inconspicuously setose. Regions sufficiently distinct about the middle, separated by linear sulci. Lateral margins of the dorsum raised; posterior-lateral tooth spiniform, sharply prominent; anterior tooth not prominent. Dorsal margin distinct across the base of the rostrum. Median tooth of rostrum styliform, slender and setose; lateral teeth extremely slender and sharp. Chelipeds weak; meros with a tooth at the summit; hand slender; fingers as long as the palm. Ambulatory feet very slender, minutely



CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

setose; teeth as in the preceding species, but more minute and sharper; dactyli longer than in the preceding species and more slender, those of the posterior pair of feet much more curved than the rest. Dimensions of the carapax: Length, 0.19; breadth, 0.175 inch.

Found at Hongkong, China.

LEUCOSIDEA

Genus LEUCOSIA (Fabricius) Leach

The species of this genus which have recently become known are very numerous, and although the distinctive marks are generally so slight as to be determined with difficulty from descriptions or figures, they are nevertheless perfectly plain and satisfactory when seen in the specimens themselves. The doubts thrown upon the validity of some of the numerous species of Bell by certain German authors are entirely unfounded; for several characters of a kind which, in other genera of Brachyura, are merely indicative of variety or individual peculiarities, here become of specific importance. Color, for instance—usually and very properly disregarded as being variable and of no specific value in most crabs—is in the genus *Leucosia* a constant and important character.

In *Leucosia* the plane of the chelipeds is much more oblique to the plane of the carapax than in most crabs, so that in their usual position the anterior extremity is much elevated. They have usually been delineated in this position, so that the post-brachial angle of the inferior lateral margin cannot be seen. In our drawings we have endeavored to represent the carapax in its own plane.

In the larger pair of male abdominal appendages the spiral is well marked, and shows in the different species a number of turns varying from one and a half to eight or ten.

245. LEUCOSIA VITTATA[1] Stimpson

PLATE XVIII, FIG. 3, 3*a*

Leucosia vittata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 159 [57], 1858.

Carapax rhomboidal, strongly convex; breadth to length as 1 : 1.14. Surface punctate. Margins crenulated; granules of antero-lateral margins not conspicuous from above. Posterior margin straight, granulated, obtuse in the adult, rather projecting in the

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[1] *Leucosides vittata* (Stimpson).

young, with a sharp tooth at each extremity. Front sufficiently projecting, tridentate, the median tooth a little more prominent than the lateral ones. Thoracic sinus very deep, pubescent, with no tubercles, its antero-exterior notch reaching the margin of the carapax, its inner notch deep and narrow, reaching nearer to the base of the exognath of the outer maxillipeds than in most other species. The meros-joint of the chelipeds is somewhat contracted and pubescent about the base, and ornamented along the margins with tubercles rather sparsely distributed. There are no tubercles on its upper surface excepting five close to the base, almost concealed by the pubescence, of which two are large; beneath there are a few tubercles scattered near the base. The hand is large. Ambulatory feet with somewhat dilated joints. Tubercle of the penult joint of the abdomen minute. The male abdomen resembles that of *L. rhomboidalis,* but is more slender and tapering. The male abdominal appendages show two or three turns in their spiral.

Colors in life: The carapax is bluish-white, with a median dorsal band of reddish becoming broader posteriorly, and two oblique bands of red on each side diverging from the front, and also widening posteriorly. Feet clouded transversely with reddish, almost annulated. Beneath the body is white, and the feet paler than above. Dimensions of the carapax in a male: Length, 0.97; breadth, 0.85 inch.

This species differs from *L. craniolaris* in the pubescence at the base of the arms; from *L. rhomboidalis,* to which it is still more closely allied, in its distinctly tridentate front.

It was taken with the trawl from muddy bottoms, in four or five fathoms, in the bays on the Chinese coast, near Hongkong.

246. LEUCOSIA MACULATA[1] Stimpson

PLATE XVIII, FIG. 2

Leucosia maculata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 159 [57], 1858.

This species is much smaller than any other of the group of *Leucosiæ* to which it belongs. The carapax is rhomboidal, smooth and glossy, longer than broad, in the proportion of 1 : 1.16. The front is tridentate, with tips a little deflexed; the median tooth is much the largest and most prominent, the lateral ones being scarcely prominent enough to be considered teeth. Thoracic sinus very deep,

[1] *Leucosides rhomboidalis* (De Haan).

pubescent, not tuberculated, with no notch at the antero-interior angle, which is broadly rounded. Posterior margin convex, not projecting, lightly granulated; angles obtuse. Meros-joint of the chelipeds as in *L. vittata,* with the base pubescent; the marginal tubercles are, however, more crowded. In the abdomen of the male the antepenult joint is contracted toward its extremity, and there is a constriction at the commissure of this joint with the penult. The tubercle of the penult joint is sufficiently large, and the surface in front of it excavated. The male abdominal appendages are spiral, with two turns.

The life colors are as follows: Carapax bluish-brown, becoming paler posteriorly, and spotted with red, there being five small spots on each side of the median line, placed in arcuated series, which diverge anteriorly. Chelipeds bluish-brown; walking feet white, barred with red. Dimensions of the carapax in a male: Length, 0.58; breadth, 0.5 inch.

This species also is allied to *L. rhomboidalis,* but differs in the form of the abdomen.

It was dredged in considerable numbers on a shelly-mud bottom, in twenty fathoms, off the coast of China, near Hongkong.

247. LEUCOSIA PARVIMANA[1] Stimpson

PLATE XVIII, FIG. 1

Leucosia parvimana STIMPSON, Proc. Acad. Nat. Sci. Phila., x, 159 [57], 1858.

Carapax longer than broad, in the proportion of 1 : 1.15; very convex posteriorly; sides rounded; surface near the antero-lateral margins concave. Apex (or anterior extremity) compressed and much directed upward. Front projecting beyond the orbits, tridentate, the median tooth most prominent. Antero-lateral margin moderately crenulated, not extending further back than the first pair of ambulatory feet. Postero-lateral or inferior margin inconspicuously crenulated. Posterior margin obtuse, minutely crenulated above, smooth and glossy beneath. Thoracic sinus shallow, anteriorly abbreviated, but with deep notches at the corners, and ornamented with three large and two or three small tubercles above the base of the arm. The meros-joint of the chelipeds is tuberculated above on the basal half, as in *L. pallida,* the tubercles rather large; below, about the anterior edge, it is crowdedly tuberculated. The hand is

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[1] *Leucosides parvimana* (Stimpson).

small, with the external edge acute; inner edge obtuse, slightly crenulated above; fingers short and weak, much gaping, and smooth within. The dactyli of the ambulatory feet are slender, not dilated, as in some species.

Beneath the surface is milk white and polished, shining. The sutures of the sternum are deeply impressed, and its postero-lateral angles tuberculiform. The abdomen of the male is moderately broad, the antepenult joint protuberant on either side of the median line; penult joint with convex sides, and armed with a sharp tubercle near the middle, pointing backward. The male abdominal appendages exhibit a beautifully close sharp spiral of seven or eight turns.

This species is of a pale buff color, clouded with darker gray on the anterior part of the carapax, which is also variegated with three white spots on each side of the median line, and two dark spots posteriorly. Dimensions of the carapax in the male: Length, 0.84; breadth, 0.73 inch.

This species approaches nearest to *L. pallida* Bell, from which it may be distinguished in its less strongly crenulated margins, in having only three large tubercles in the thoracic sinus, and in its more slender dactyli.

Taken near Selio Island, in Gaspar Strait, by Capt. John Rodgers, of the steamer "Hancock."

248. LEUCOSIA HÆMATOSTICTA[1] Adams and White

Leucosia hæmatosticta ADAMS and WHITE, Voy. Samarang, Crust., p. 54, pl. XII, fig. 2.

In our specimen the front is more projecting than in the figure above quoted, and subtriangular. The posterior margin is also convex. In the living animal the anterior half of the carapax was bluish-white, the posterior half dotted with red; a band of crowded red punctæ across the middle, interrupted at the median dorsal line. Below white, with a few scattered red dots.

It was dredged from shelly-sand in twenty fathoms, in Kagosima Bay, Japan.

Genus MYRA Leach

249. MYRA FUGAX[2] (Fabricius) Leach

Leucosia fugax FABRICIUS, Suppl., p. 351.
Myra fugax LEACH, Zoöl. Misc., III, 24. MILNE EDWARDS, Hist. Nat. des

[1] *Leucosides hæmatosticta* (A. & W.).
[2] *Persephona fugax* (Fabricius).

Crust., II, p. 126. DE HAAN, Fauna Japonica, Crust., p. 134, pl. XXXIII fig. 1.

Our specimens agree much better with De Haan's figures than with those of Milne Edwards in the illustrations to the recent edition of Cuvier's "Règne Animal." In the young female the abdomen is scarcely wider than in the male. The color in life is pale brick red above, clouded with bluish; below whitish.

It is common on mud and shelly-mud in five to twelve fathoms, in Hongkong Harbor; also taken in twenty-five fathoms, sand, in the China Sea, near latitude 23° N.

250. MYRA AFFINIS[1] Bell

Myra affinis BELL, Lin. Trans., XXI, 296.

A young female specimen referable to this species is found among our collections, in which, however, the surface is but little granulated, as in *M. fugax*, to which it is very closely allied. But the teeth at the posterior extremity of the carapax are obtuse, and the middle one is short (perhaps worn).

The specimen in life was of a dusky brick-red color above; sides and feet paler and variegated with white; beneath white.

It was dredged from a shelly bottom in twenty fathoms, in Kagosima Bay, Japan.

Genus PHILYRA Leach

251. PHILYRA TUBERCULOSA Stimpson

PLATE XVIII, FIG. 5

Philyra tuberculosa STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 159 [58], 1858.

Description of a female: Carapax convex, broadly rhomboidal, almost orbicular, but longer than broad; proportion, 1 : 1.05. Outline angular. Surface uneven. Branchial, postero-gastric, genital, and cardiac regions protuberant and closely tuberculated. Margins granulated. Posterior margin transverse. Front concave, smooth, shorter than the epistome. Hepatic or pterygostomian angle prominent, its ridges granulated. Outer maxillipeds somewhat rugose, and ornamented with a ciliated line parallel to the inner margin. Chelipeds short; meros strongly granulated, except at the middle

[1] *Persephona affinis* (Bell).

near the extremity; hand nearly smooth, punctate, with no granulated lines within; fingers deeply sulcated, gaping at the base. Sternum closely tuberculated. Abdomen smooth, with the exception of the first and second joints, and a transverse line on the third, which are granulated. Color in life yellowish-gray. Dimensions of the carapax: Length, 0.49; breadth, 0.47 inch.

Found on coarse sand bottoms, just below low-water mark, at spring tides, in bays of the Chinese coast, near Hongkong.

252. PHILYRA PLATYCHEIRA De Haan

Philyra platycheira De Haan, Fauna Japonica, Crust., p. 135, pl. xxxiii, fig. 6.

De Haan's figure does not show the marginal granules, which are, however, mentioned in his description. The surface of the carapax, besides being punctated, is seen under the microscope to be granulated, most conspicuously so posteriorly. The color in life is a clear dark bluish-gray above, white below.

It was dredged by us from a muddy bottom at the depth of six fathoms, in Hongkong Harbor.

253. PHILYRA UNIDENTATA Stimpson

Plate XVIII, Fig. 4

Philyra unidentata Stimpson, Proc. Acad. Nat. Sci. Phila., x, p. 159 [58], 1858.

Carapax (in the female) suborbicular, longer than broad; proportion, 1 : 1.08. It is a little produced anteriorly. The lateral and posterior margins are rounded, continuous, and crenulated, the crenulations being small, equal, and obtuse. Surface perfectly smooth and glabrous. Front unidentate at the middle, but on each side straight and considerably shorter than the epistome. Outer maxillipeds flat; ischium of endognath with an inconspicuous ciliated line along the middle parallel to its inner margin. Chelipeds less than twice as long as the carapax; meros with large tubercles above on the basal two-thirds, the rest smooth; below the meros is closely small-tuberculated, except the middle and anterior portions; hand sufficiently convex; fingers short, somewhat depressed, touching each other at the terminal third only of their length; their inner margins acute, obsoletely one- or three-toothed.

Colors in life: Carapax very pale reddish-brown, with a median stripe and portions of the margin of a bluish-white color. Feet

bluish-white, banded with pale red; inner half of fingers light red. Below white. Dimensions of the carapax: Length, 0.54; breadth, 0.5 inch.

Dredged from a sandy bottom in twenty-five fathoms, in the northern part of the China Sea, latitude 23° N.

Genus EBALIA Leach

254. EBALIA MADEIRENSIS Stimpson

PLATE XVIII, FIG. 7

Ebalia madeirensis STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 159 [58], 1858.

We have but one specimen, a female, of this species. The carapax is suboctagonal, or rhomboidal, with the angles truncated, the lateral ones obliquely. It is broader than long, in the proportion of 1 : 1.07. Both the antero-lateral and the postero-lateral margins are slightly concave. The carapax is very convex across the middle, and there is a narrow median carina extending from the front to the sharply prominent and granulated cardiac tubercle. The branchial regions are prominent, irregularly granulated about their summits, the outer granules large and sharp. Front concave, minutely granulated. Posterior margin nearly straight, its surface granulated. Surface of the carapax, except at the points mentioned above, smooth and glabrous. There is a minute spine at the summit of the pterygostomian angle. The surface of the outer maxillipeds is obsoletely granulated. Chelipeds granulated, the marginal granules few, distant, and subspiniform; the meros-joint more than twice as long as broad.

Dimensions of the carapax: Length, 0.28; breadth, 0.3 inch.

Dredged from a coarse sandy bottom in twenty fathoms, in Funchal Bay, Madeira.

Genus PHLYXIA Bell

255. PHLYXIA QUADRIDENTATA (Gray) Stimpson

PLATE XVIII, FIG. 6

Ebalia quadridentata GRAY, Zoöl. Misc., p. 40.
Phlyxia quadridentata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 159 [58], 1858.

This species is much like *P. crassipes* Bell (Lin. Trans., XXI, pl. XXXIV, fig. 2) in its quadridentate front and tuberculated dorsum, but the carapax is broader, the front less produced, and the surface

minutely granulated. In the female the tubercles of the carapax are less prominent and more obtuse than in the male. The outer maxillipeds, as well as the sternum, are microscopically granulated. The chelipeds are shorter and more slender than in *P. crassipes;* the hand smooth; the fingers short, sulcated, and minutely denticulated within, but with no large tooth. The ambulatory feet are more slender. In life the carapax was mottled with white and bluish-gray; the feet and chelipeds usually annulated or banded. The dimensions of a female are: Length of carapax, 0.4; breadth, 0.38 inch.

On shelly ground in two fathoms, near the mouth of Port Jackson, Australia.

Genus ARCANIA Leach

256. ARCANIA GLOBATA Stimpson

PLATE XVIII, FIG. 9

Arcania globata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 160 [58], 1858.

Of this species two females were taken, to which the following description will apply: Breadth to length as 1 : 1.05. The carapax, leaving out the protruded front, is regularly and evenly globular—the regions not being circumscribed—and thickly covered above with small, sharp, scarcely granulated spines, ten of which, around the margins, are a little longer than the others. A median spine on the post-cardiac region is also somewhat larger than the others. Between the two large spines on the posterior margin there are two small ones. Frontal region nearly smooth, posteriorly minutely spinulose; frontal margin regularly concave, arcuated, terminating in a small tooth at each extremity. Chelipeds closely granulated, granules mostly subspiniform, those of the hand much smaller than those of the meros-joint. Fingers slender, as long as the palm. Ambulatory feet smooth.

Color in life pale brick red above, with a longitudinal wedge of white margined with brown, the apex of which is at the middle of the carapax, the base covering the front. Beneath white, tinted with reddish. Dimensions of the carapax: Length, 0.46; breadth, spines included, 0.44 inch.

The carapax in one of the specimens is somewhat more depressed.

It differs from *A. erinaceus* in wanting spines on the ambulatory feet; from *A. tuberculata* and *A. levimana* in having sharp instead of tuberculiform spines.

It was dredged in sixteen fathoms, on shelly and gravelly mud, off the coast of China, near Soon-Koo and Hongkong Islands; also in the North China Sea, in latitude 23° N., at the depth of twenty-five fathoms.

Genus IPHIS Leach

257. IPHIS SEPTEMSPINOSA[1] (Herbst) Leach

Cancer septemspinosus HERBST, Naturg. d. Krabben und Krebse, I, pl. XX, fig. 112.
Leucosia septemspinosa FABRICIUS.
Iphis septemspinosa LEACH, MILNE EDWARDS, Hist. Nat. des Crust., II, 139; Illust. Cuv. R. A., Crust., pl. XXV, fig. 4. BELL, Lin. Trans., XXI, 311.

The color in life is pale brick-red above, white below. In one of our specimens the width between the tips of the lateral spines is 2.15 inches. In the young these spines are proportionally shorter.

Several specimens were taken in the trawl on a muddy bottom in twenty fathoms, off the coast of China, near Hongkong.

Genus IPHICULUS Adams and White

The affinities of the crustaceans upon which this genus was founded have been hitherto a matter of conjecture only, owing to the imperfect manner in which it was characterized by its original describers, and their doubtful reference of it to two very distinct groups of Brachyura, the Parthenopidæ and the Leucosidea. They place it, indeed, among their descriptions of Leucosidea, but say in their note that "it appears, among the Parthenopidæ, to hold the same place as *Oreophorus* does among the Leucosidæ." While, curiously enough, the generic name which they have applied to it is a diminutive of that of its nearest congener *Iphis*, and thus indicates its true position.

Dana, having only the figures of Adams and White to judge from—the characters of the antennæ, maxillipeds, and other essential parts generally not being mentioned in their description—considered it allied to or identical with *Polydectus*,[2] from the similar character of the hand, in which the long, slender fingers are armed with needle-like spines along their inner margins. This kind of

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[1] *Arcania septemspinosa* (Fabricius).
[2] U. S. Exploring Expedition, Crust., I.

hand, however, is not uncommonly seen among true Leucosidea, such as *Nursilia dentata* and *Myrodes eudactylus,* for instance.

Bell does not include the *Iphiculus* in his "Monograph of the Leucosidæ," although he states that it is "most probably associated with them."[1]

From the structure of the maxillipeds and other important parts, this crab seems evidently allied to *Iphis* and *Oreophorus.* Its carapax is indeed much broader than in any other Leucosidian genus, the front is not all produced, and the epistome is quite large; but the spines of the carapax are much like those of *Iphis,* though differing in number and position. This is best shown when the body is denuded of pubescence, as in pl. XVIII, fig. 8*a*.

With regard to the mouth parts we may observe the following points: The mandibles resemble those of *Iphis,* but the apex of the corona is obtusely rounded. The maxillipeds of the inner pairs are exactly like those of *Iphis.* The outer maxillipeds are much shorter than is usual in the tribe, each of them being more than half as broad as long. They are convex, much bending upward anteriorly to follow the curve of the body. The exognath is somewhat shorter than the endognath, and nearly two-thirds as broad; the apices of these two branches are separated by the inner wall of the pterygostomian channel, which here projects strongly between them. The surface of the exognath is sharply granulated at the middle and toward the outer margin, which is straight; its apex is obtuse. The endognath longitudinally sulcated or divided into two portions, the inner half being depressed and smooth, the outer prominent and granulated; the meros is triangular, less than two-thirds as long as the ischium; the commissure of these two joints is oblique, and angular at the middle. The pterygostomian channels are deep; the walls at the anterior extremity strongly projecting and arcuated, interrupted at the exterior angle by a very deep notch, rounded and somewhat widened at the bottom, and near the interior angle by a shallower notch, separating the main length of the inner margin from the dilated lobe at its anterior extremity. The anterior margin of the palate is dilated, much projecting at the middle, but not as far as the extremities of the pterygostomian channels.

The orbits are nearly transverse, but the eyes can be thrown forward into a longitudinal direction.

[1] Lin. Trans., XXI, 312.

258. IPHICULUS SPONGIOSUS Adams and White

PLATE XVIII, FIG. 8

Iphiculus spongiosus ADAMS and WHITE, Voy. Samarang, Crust., 57, pl. XIII, fig. 5.

It is covered with a villous coat of a dirty buff color, paler below, with a transverse band of purple-brown at the epistome.

When captured it feigns death like a spider, contracting or folding up all its members closely against the body in a very compact form, to which the shape of the sides of the body shows an adaptation.

It was dredged on muddy bottoms, sometimes on muddy gravel, in from ten to twenty fathoms, in the bays and channels of the Chinese coast, near Hongkong.

Genus OREOPHORUS Rüppell

259. OREOPHORUS RUGOSUS Stimpson

PLATE XIX, FIG. 6, 6*a*

Oreophorus rugosus STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 161 [59], 1858.

Carapax subpentagonal, and much broader than long, in the proportion of 1 : 1.38. It is rugose, as if eroded or vermiculated, with a series of oblong pits parallel to the antero-lateral margins, and a longitudinal series on each side of and almost circumscribing the cardiac region. Front narrow, prominent. Branchial regions much projecting laterally, somewhat concave, and partly covered with flattened or subcapitate tubercles, which extend to the posterior margin of the carapax, where they become confluent. Chelipeds rugose, eroded, and irregularly protuberant; fingers sulcated, of moderate breadth, concave on the upper or inner side, and with sharp curved tips placed laterally; immovable finger broader than the dactylus. Ambulatory feet moderately tuberculated along their edges, the tubercles small. Abdomen covered with small rounded tubercles, not crowded, and marked with two interrupted impressed lines down the middle, which circumscribe the median carina, which is, however, less convex than the sides.

This species is of an ashy-white hue, but much discolored by sordes. The dimensions of the female specimen above described are: Length of carapax, 0.48; breadth, 0.662 inch.

It is perhaps specifically the same as the example figured by Adams and White in pl. VI, fig. 2, of the Crustacea of the Voyage of the Samarang, which is considered by the authors to be the young of their *O. reticulatus.*

Found at Loo Choo.

Genus NURSIA Leach

260. NURSIA PLICATA[1] (Herbst) Bell

Cancer plicatus HERBST, Naturg. d. Krabben u. Krebse, III, pl. 59, fig. 2.
Nursia hardwickii LEACH, Zoöl. Misc., III, p. 20.
Nursia plicata BELL, Lin. Trans., XXI, 307, pl. XXXIV, fig. 4.

The middle portion of the carapax in our specimens is closely granulated, and sometimes the ridges also. The hand is depressed, and nearly smooth; the fingers sulcated. In life the color of the carapax above is partly pale brick-red and partly yellowish-white: the arms are reddish; the hands pale buff.

It was dredged in considerable numbers from shelly bottoms in six to ten fathoms, in the channel of Hongkong Harbor.

261. NURSILIA DENTATA Bell

Nursilia dentata BELL, Lin. Trans., XXI, 309, pl. XXXIV, fig. 6.

In the male specimen taken by us we notice the following characters. The posterior branchial angle and ridge are acutely prominent, forming a sharp up-curved tooth at the margin, which is almost as prominent as the lateral tooth anterior to it. The front is broader than in Bell's figure, and the teeth more projecting. Eyes protractile to a considerable length. Antennulæ very long, nearly half as long as the carapax; their fossæ very deep. The external maxillipeds are not gaping, as in the female, according to Bell; the surface of the exognath is granulated; ischium of endognath with a longitudinal ridge along the middle; meros excavated. Chelipeds as in the female. Abdominal segments as in *Nursia;* penult joint with a tooth near its extremity, pointing backward. The abdominal appendages of the first pair are bifurcated at their extremities.

Color in life white. Dimensions of the carapax: Length, 0.27; breadth, 0.29 inch.

The difference in the outer maxillipeds is so great that were it not for the exact correspondence of some other characters we should

[1] *Nursia hardwickii* Leach.

consider it specifically, or even generically, different from *Nursilia dentata*. It certainly shows a much greater difference between the male and female than is noticed in other genera of the family. The variation, however, when it exists, is usually found in the outer maxillipeds, as the ciliated ridge in the female, etc.

Our specimen was dredged in ten fathoms, sandy bottom, in the straits separating Katonasima from Ousima.

CRYPTOCNEMIDÆ

A small but well-marked group of Leucosidea may be separated under this title, including the genus *Tlos* White (which we conclude to be a Leucosidian, notwithstanding Bell's footnote[1]), and the three new genera described below. They are analogous to *Cryptopodia* among Parthenopidæ and to *Cryptolithodes* among the Lithodidæ, being characterized by a broad, flattened, or even concave, carapax, the margins of which are expanded and lamelliform, projecting so much as to conceal the ambulatory feet for the whole or a part of their length. The chelipeds are, as in *Cryptopodia*, large, depressed and always exposed. The apex of the outer maxillipeds is sharply triangular, projecting much beyond the extremity of the exognath, and dividing the epistome into halves. The exognath is generally dilated, and its outer margin more or less arcuated. The basal joint of the outer maxillipeds is rather small. The pterygostomian channels are broadly excavated, with the inner margin distinct and projecting only at the anterior extremity, posteriorly sloping off smoothly inwards. The orbits are small and deep, and the outer antennæ obsolete, or nearly so. In the male abdomen the segments seem to be mostly soldered together, the first and last being, however, always distinct.

The crabs of this family would appear to have their nearest allies among ordinary Leucosidæ in *Oreophorus, Nursia,* and *Nursilia.*

Genus CARCINASPIS Stimpson

Carapax suborbicular, depressed, nearly flat, broader than long, broadly rounded but not expanded posteriorly. Sides expanded, but not projecting sufficiently to conceal entirely even the meros-joints of the ambulatory feet. Front rostrate; rostrum short, broadly truncated. Eyes concealed beneath the carapax. Orbits very deep, round, without fissures, closed within and not communi-

[1] Lin. Trans., XXI, p. 278.

cating with the antennulary fossettes. These fossettes are transverse, ovate in shape, small and complete. The epistome is sufficiently large on either side of the apex of the maxillipeds which divides it. Buccal area as broad as long. Pterygostomian channels notched at the antero-exterior side. Exognath of the outer maxillipeds small, much narrower than the endognath; meros-joint of endognath three-fourths as long as the ischium. Chelipeds robust, not crested; fingers nearly longitudinal. In the female abdomen the segments from the third to the sixth are soldered, and the second segment is produced into a point on either side. The sternum is broad.

262. CARCINASPIS MARGINATUS Stimpson

PLATE XIV, FIG. 7

Carcinaspis marginatus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 161 [59], 1858.

In the female specimen which we have before us the proportion of length to breadth in the carapax is 1 : 1.12. The carapax is smooth and glabrous above, slightly convex and punctate at the middle, and margined with a double series of minute granules. Rostrum produced, slightly elevated. Beneath the subhepatic regions the margins of the outer maxillipeds and sternum are closely granulated, the granules rather flattened. Chelipeds robust, angular, the surfaces smooth, the upper surface margined on either side, like the carapax, with a double series of granules, the inferior keel often punctate or inconspicuously granulated. Fingers of the hand sulcated, half as long as the palm. Ambulatory feet rather broad; meros unicarinate above; remaining joints to extremities bicarinate, upper carina most prominent; dactyli as long as the penult joint and with acute extremities.

In life carapax red; feet white. Dimensions of the carapax: Length, 0.25; breadth, 0.28 inch.

Found under stones at low-water mark, on rocky shores, at the Cape of Good Hope.

Genus CRYPTOCNEMUS Stimpson

The carapax is broad and pentagonal in shape, or perhaps better described as triangular, with the lateral angles truncated. It has broad laminiform expansions posteriorly and at the sides, concealing the ambulatory feet, with the exception of their extremities when extended. The lateral expansions and the front are bent upward,

so that the upper surface is concave on either side of the dorsal convexity, which is almost carinate along the middle. The front is rostrate; the rostrum broad and triangular, pointing obliquely upward. Orbits minute, round, with entire margins. Antennulary fossæ oblique. External antennæ nearly obsolete, or represented only by one or two joints at the base. Epistome sufficiently large. Buccal area as broad as long. Anterior margins of the pterygostomian channel entire. Exognath of the outer maxillipeds dilated, as broad as the endognath, its outer margin broadly and regularly arcuated. Meros-joint of the endognath two-thirds as long as the ischium. Chelipeds with laminiform crests at the edges; fingers of the hand short. Dactyli of the ambulatory feet very narrow. Sternum broad. Abdomen of the male narrow-triangular, geniculated near the base (where, however, there is no *joint*) in a right angle, its segments all confluent with the exception of the first and last.

This little crab has much resemblance to a *Cryptopodia*, and in its natural position the main body of the carapax anteriorly is directed obliquely upward and forward at an angle of 45°.

263. CRYPTOCNEMUS PENTAGONUS Stimpson

PLATE XIV, FIG. 5, 6

Cryptocnemus pentagonus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 162 [60], 1858.

Carapax much broader than long in the proportion of 1 : 1.45. The length of the postero-lateral side is one-half that of the antero-lateral. The surface is perfectly smooth and glabrous, and convex anteriorly, with a slight longitudinal ridge or carina running from the tip of the rostrum to the middle of the gastric region. The small cardiac region is slightly prominent. The rostrum is elevated to an angle of about 60° with the horizon; tip almost acute; sides convex. The outer maxillipeds and all the lower surfaces of the body are smooth and glossy. The chelipeds are flattened, with glabrous surfaces; the marginal laminæ very much expanded, that of the hand being wider than the slight thickening which constitutes its body, and deeply notched on the outer side near the fingers. The fingers are one-third as long as the palm; immovable finger broad; dactylus sulcated. Ambulatory feet crested with laminæ; dactyli very slender. Color of preserved specimen white. Dimensions of the carapax in the male: Length, 0.2; breadth, 0.29 inch.

Dredged from shelly mud in twenty fathoms, in Kagosima Bay, Japan.

Genus ONYCHOMORPHA Stimpson

Carapax flat, unguiform, longer than broad, posteriorly broadly expanded and laminiform, anteriorly narrowing. Front very short, truncated, non-rostrate, and scarcely as prominent as the epistome. Orbits very minute, deeply notched or fissured at the middle above, and with a small hiatus within. Antennulary fossæ oblique. Epistome very small. External antennæ obsolete. Buccal area longer than broad. Anterior margins of pterygostomian channel entire. Basal joint of outer maxillipeds very small; exognath much broader than endognath, with arcuated outer margin; endognath very slender, its apex projecting less far beyond that of the exognath than in the other genera of this family; ischium-joint shorter than the meros. Chelipeds much depressed, hand almost laminiform, fingers very short, oblique, almost transverse. Sternum of moderate breadth. Abdomen of the male subtriangular, broad and tumid near the base, sides toward extremity a little concave, segments confluent except at base and extremity.

This genus is easily recognized by the great expansion posteriorly of the carapax and the non-rostrate front.

264. ONYCHOMORPHA LAMELLIGERA Stimpson

PLATE XIX, FIG. 8, 8a

Onychomorpha lamelligera STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 162 [60], 1858.

Carapax almost laminiform, somewhat lyre-shaped, broadest at the posterior extremity, narrowing anteriorly, and deeply sinuated or contracted at the level of the third pair of feet. Breadth to length as 1 : 1.1. Front very short; margin straight. Antero-lateral and posterior margins somewhat curved, convex. Upper surface glabrous, lightly convex about the middle, depressed and faintly radiated toward the margins. Pregastric region depressed below the level of the front. Outer maxillipeds and lower surfaces of the body smooth. Chelipeds smooth; meros trigonal but depressed, with sharp edges; carpus small, with acute exterior edge; hand much dilated, lamelliform, pubescent at inner edges and lower surface; fingers deeply sulcated, constituting one-fourth the length of the hand. Ambulatory feet slender, with no laminiform expansion; dactyli slender as in *Cryptocnemus pentagonus*. Abdomen of the male with a sharp tooth at the extremity of the penult joint and

a rounded swelling or convexity of the surface on each side near the base. Dimensions of the carapax in the male: Length, 0.242; breadth at the posterior extremity, 0.22 inch.

It was dredged from a shelly-mud bottom in ten fathoms, in Hongkong Harbor, China.

CALAPPIDEA

Genus CALAPPA Fabricius

265. CALAPPA CRISTATA[1] Fabricius

Calappa cristata FABRICIUS, Suppl., 346; MILNE EDWARDS, Hist. Nat. des Crust., II, 105.
Lophos philargius DE HAAN.

In life the color is pale brick-red above, the surface being covered with crowded punctæ of that color. The eyes are longitudinally striped with black, the stripes or lines being about seven in number. A large, well-defined deep red spot on the carpus, and one on the front of the hand. Inner side of hand with red spots or blotches arranged in lines. Lower side of brachia deep red. Inferior surface of body white, with the exception of two oblique red lines on each cheek.

It is not uncommon on muddy bottoms at about six fathoms depth in the vicinity of Hongkong, China. It occurred abundantly in May, 1854, but none were found later in the season. Taken also at Loo Choo.

266. CALAPPA TUBERCULATA[2] Fabricius

Calappa tuberculata FABRICIUS, Suppl., 345. HERBST, Naturg. d. Krabben u. Krebse, I, 204, pl. XIII, fig. 78. DESMAREST, Consid. sur les Crust., 109, pl. X, fig. 1. MILNE EDWARDS, Hist. Nat. des Crust., II, 106. DANA, U. S. Expl. Exped., Crust., I, 393.
Calappa hepatica DE HAAN, Fauna Jap., Crust., p. 70.

Found by the expedition in Gaspar Strait and at Loo Choo.

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[1] *Calappa philargius* (Linnæus).
[2] *Calappa hepatica* (Linnæus).

Genus CYCLOËS De Haan

267. CYCLOËS CRISTATA [1] (Brullé) Stimpson

PLATE XIX, FIG. 7

Cryptosoma cristata BRULLÉ, in MILNE EDWARDS, Hist Nat. des Crust., II, 110; in WEBB and BERTHELOT, Hist. Canaries, Crust.
Cycloës cristata STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 162 [60], 1858.

Dredged in twenty fathoms, coarse sandy bottom, in Funchal Bay, Madeira.

Genus MATUTA Fabricius.

268. MATUTA LUNARIS [2] (Herbst) Leach

Cancer lunaris HERBST, Naturg. d. Krabben u. Krebse, III, p. 43, pl. XLVIII, fig. 6.
Matuta lunaris LEACH, MILNE EDWARDS, Hist. Nat. des Crust., II, 114. DANA, U. S. Expl. Exped., Crust., I, 395.

In the living specimen the carapax is bluish-white, delicately reticulated with threads of dark red dots. A large white spot on the gastric region. Feet pale whitish, with a few red-dotted lines. Eyes gray, tipped with white; peduncles white. Below pure white.

Taken with the seine on sandy beaches in Port Lloyd, Bonin Island.

A specimen was also found swimming off Rosario Island. This was of a dark purplish-red color, minutely reticulated with yellow-dotted threads.

269. MATUTA VICTOR [3] Fabricius

Matuta victor FABRICIUS, Suppl., 369. MILNE EDWARDS, Hist. Nat. des Crust., II, 115; Illust. Cuv. R. A., Crust., pl. VII, fig. 1. DANA, U. S. Expl. Exped., Crust., I, 395.

In life carapax bluish or yellowish, with numerous scattered red dots. Feet yellowish, with large red dots at the joints. Beneath white.

Found on coarse sand, a fathom below low-water mark, at Hongkong; also dredged in the North China Sea.

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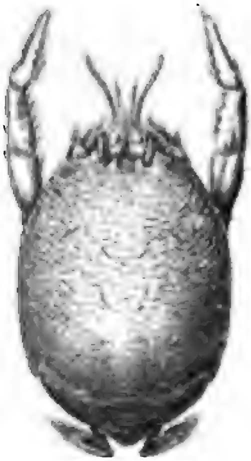
[1] *Cycloës dentata* (Brullé).
[2] Probably *Matuta planipes* Fabricius.
[3] Probably *Matuta lunaris* (Forskål).



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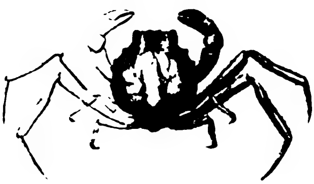

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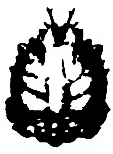

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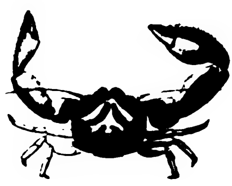

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CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

DORIPPIDÆ

Genus DORIPPE Fabricius

270. DORIPPE QUADRIDENS[1] Fabricius

Dorippe quadridens FABRICIUS, Suppl., 361. DE HAAN, Fauna Japonica, Crust., 121, pl. XXXI, fig. 3.
Dorippe quadridentata MILNE EDWARDS, Hist. Nat. des Crust., II, 156.

The so-called teeth of the abdomen in this species are large, round, glossy tubercles, of a bright orange color, and very conspicuous among the rough hairy coatings which cover the general surface of the body. The bare surfaces of the last two joints of the chelipeds and long ambulatory feet are also of a deep orange color in life. Beneath the naked parts are white.

In the examination of a considerable number of specimens we find that the eyes in the young are very long, reaching beyond the tips of the extra-orbital spines, while in full-grown individuals they do not reach even to the extremities of these spines.

Dredged in six and eight fathoms, on gravelly-mud bottoms, in Hongkong Harbor.[2]

272. DORIPPE JAPONICA Von Siebold

Dorippe japonica VON SIEBOLD, Spicilegia Faunæ Japonicæ, 14. DE HAAN, Fauna Jap., Crust., p. 122, pl. XXXI, fig. 1.

Fragments of a large male of this species, including the peculiar hand, were dredged in the harbor of Hakodadi.

273. DORIPPE GRANULATA De Haan

Dorippe granulata DE HAAN, Fauna Japonica, Crust., p. 122, pl. XXXI, fig. 2.

Color in life reddish above, white below.

Dredged on a mud bottom in six fathoms in the Bay of Hakodadi, Japan; also in thirty fathoms off the northeast coast of Niphon, and in ten fathoms in Hongkong Harbor.

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[1] *Dorippe dorsipes* (Linnæus).
[2] No. 271, *Dorippe facchino*, is missing from the manuscript.—Editor.

Genus ETHUSA Roux

274. ETHUSA SEXDENTATA[1] (Stimpson)

PLATE XIX, FIG. 4

Dorippe sexdentata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 163 [61], 1858.

Of this small species a single male individual was obtained. It presents characters which may, upon further examination, warrant its separation from the typical *Ethusa.* The carapax is narrowed forwards; proportion of breadth to length, 1 : 1.13. The surface is uneven, but not granulated. Inter-ocular front quadridentate; teeth very sharp, subequal, in two pairs separated by the median notch. Extra-ocular teeth sharp and spiniform, about equal to the frontal teeth in size, but not reaching to the level of their tips. Infra-orbital spine obsolete. External maxillipeds naked, longitudinally sulcated; meros nearly as broad as ischium. Inner maxillipeds as in *Dorippe.* The epignath of the outer maxillipeds plays in a large afferent cavity at the base of the pterygostomian region, which is not, however, separated, as in *Dorippe,* from the open space at the base of the chelipeds. The feet are slender, rounded and roughened with slight asperities.

In life carapax pale yellowish-gray; feet pale brownish; fingers of the hand white. Dimensions of the carapax: Length, 0.275; breadth, 0.242 inch.

It was dredged from a shelly bottom in twenty fathoms, in Kagosima Bay, Japan.

Genus TYMOLUS Stimpson

Body oblong. Carapax much shorter than the body, rounded, abruptly contracted anteriorly, the facial region being narrow and protruding. Hepatic and branchial regions ample, swollen. Afferent branchial opening normal in position, at the anterior base of the chelipeds. Front quadridentate. Between the median teeth of the front a small tooth may be seen from above, which constitutes the wall of the apex or anterior extremity of the buccal area and encloses the tips of the outer maxillipeds. Orbits deep, longitudinal;

[1] This species was first transferred to the genus *Ethusa* by Stimpson, on the cover of one of the separates of the "Prodromus" (teste S. I. Smith).

superior fissure or notch deep; inferior fissure occupied by a tooth. Eyes small and protractile, as in the Leucosidea. Antennulæ sufficiently long, without fossettes, and situated in the large inner hiatus of the orbit. Antennæ short, placed in the lower angle of the orbital hiatus, beneath the antennulæ. External maxillipeds very much elongated, slightly gaping, but accurately fitting the margins of the buccal area and anteriorly concealing the apices of the inner maxillipeds; exognath very narrow, and barely overreaching the ischium of the endognath anteriorly; meros of endognath broader than the ischium, longitudinally sulcated along the middle and much produced anteriorly, its pointed apex reaching the front; palpus concealed as in the Leucosidea. Ambulatory feet as in *Dorippe,* but with the dactyli scarcely falciform and non-costate. Abdomen nearly as in *Dorippe,* but sexarticulate, and with the last joint dilated. The male verges are in the coxæ of the last pair of feet.

In the shape of the carapax this curious form resembles *Homola.* In general appearance and the structure of the feet, the posterior two pairs of which are turned up over the back and prehensile, it is closely allied to *Dorippe.* But the character of the external maxillipeds and the position of the afferent branchial openings would far remove it from this latter genus, and even entitle it to rank as a distinct family.

275. TYMOLUS JAPONICUS Stimpson

PLATE XIX, FIG. 3, 3*a*

Tymolus japonicus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 163 [61], 1858.

Carapax nearly as long as broad, conspicuously areolated, the surface minutely granulated. Sides convex, tridentate, the first tooth at the summit of the hepatic region, the other two somewhat smaller than the first, and placed rather close together on the branchial region. Teeth of the front small but sharp, the two median ones most projecting. Chelipeds of the male rough with granules and spinules and some short setæ; a strong spine at the summit of the carpus; hand short and high; fingers large, longer than the palm, concave within. Ambulatory feet very slender.

Color above bluish-gray in life, below dirty light brownish. Dimensions of the carapax in a male: Length, 0.235; breadth, 0.24 inch.

This pretty little species was dredged on a shelly bottom in eight fathoms, in the Bay of Hakodadi.[1]

ANOMURA

TELEOSOMI

Genus DROMIDIA Stimpson

The group which we have separated from *Dromia,* under the generic title of *Dromidia,* is very closely allied to the old genus restricted, in form and general appearance. The following characters may be mentioned as distinguishing it, some of which, however, may not prove to be of generic value when additional species shall be discovered. The carapax is convex and pilose, the hair or setæ being often of considerable length. The front is narrow, and the hepatic regions more or less concave or excavated anteriorly. The palate is marked by a strong ridge on either side. The posterior feet are similar to those of *Dromia,* but the last pair is generally longer than the penult pair. The appendages to the penult joint of the abdomen are minute and concealed. In the sternum of the female the copulatory sulci are produced, and approximated at their extremities in a more or less tuberculiform projection situated between the bases of the chelipeds.

In the typical species, *D. hirsutissima,* the palpus of the outer maxillipeds is articulated to the meros rather at its apex than at its inner angle, as noticed by De Haan. This, however, results from the elongation of the meros-joint and the obliquity of its anterior margin. It does not seem to be a character of much importance, and is not seen in other species of the genus.

As in former descriptions of *Dromiæ* no mention is made of characters which are here considered generic, it will be impossible to arrange all of the known species into groups without a re-examination of the specimens; but we conjecture that *D. globosa, gibbosa, unidentata,* and *rotunda* will be found to belong in the present genus.

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[1] HAPALOCARCINIDÆ

HAPALOCARCINUS MARSUPIALIS Stimpson

PLATE XIV, FIG. 8

Proc. Boston Soc. Nat. Hist., VI, p. 412, 1859. Rathbun, Bull. U. S. Fish Comm. for 1903, part III, p. 892, 1906.

Not mentioned in the manuscript of this report.

Hilo, Hawaii, 1 fathom (Stimpson).

276. DROMIDIA SPONGIOSA Stimpson

PLATE XX, FIG. 1

Dromidia spongiosa STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 238 [76], 1858.

The only specimen obtained of this small species is a female. With the exception of the fingers of the chelipeds, the entire surface is covered with a dense and firm envelope of pubescence, sponge-like in appearance. On the carapax this covering is distinctly marked with shallow pits or depressions corresponding with those of the surface beneath, which is glabrous, and minutely punctate. The front is triangular, pointed, and very much deflexed, much projecting downward, and deeply channeled longitudinally, so that it presents a bicuspid appearance from above. Its margins are smooth, though flexuose, arching over the antennæ, and presenting a slight tooth at the inner angle of the orbit. There is no tooth on the superior margin of the orbit, and none at its external angle, although at this latter point there is a fissure. The antero-lateral margin is entire, strongly convex, and bears a small tooth at the lateral emargination. The meros-joint of the external maxillipeds is oblique at the anterior margin, though less so than in *D. hirsutissima*. Chelipeds of moderate size, with a smooth surface; hand rather short; fingers not deflexed, and bare of pubescence except at their bases; both fingers toothed within. Feet of the fourth pair very short, compressed, and truncate at the tip; fifth pair more slender and longer. Abdomen (of the female) long, with a narrow, obtuse median carina separating two longitudinal smooth channels; appendages of the penult joint concealed; terminal joint large, one-half longer than the penult. Color in life reddish. Length of the carapax in our specimen, 0.42; breadth, 0.52 inch.

This species resembles somewhat *D. unidentata* Rüppell and *D. rotunda* MacLeay, from which it differs (judging from published accounts) in the want of tubercles at the angles of the orbits, in the toothed dactylus of the chelipeds, and in the shape of the meros-joint of the outer maxillipeds. *D. unidentata* is represented in Rüppell's figure as having two or three spiniform processes beside the dactylus, at the extremity of the penult joint, in the fourth and fifth pairs of feet, which is not the case in our species, nor in any other *Dromia* which we have seen.

Our species was dredged from a rocky bottom in twenty fathoms, in False Bay, Cape of Good Hope.

277. DROMIDIA EXCAVATA Stimpson

Dromidia excavata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 239 [77], 1858.

The following description was taken from a young female specimen. The body and feet are covered with pubescence which is longest beneath. Carapax smooth, strongly and regularly convex, equally so anteriorly as posteriorly. The sides are nearly parallel, so that it has a quadrate appearance, were it not for the protrusion of the front. The sides of the carapax below the sulcus, where protected by the retracted feet, are membranaceous. This is probably a mark of immaturity. The subhepatic regions are deeply excavated in front. Front small, bifid as seen from above, but with a smaller, slender, curved, acute, median tooth below; tooth over eye peduncle small, external orbital angle not dentiform. No teeth on antero-lateral margin except that forming the external angle of the hepatic excavation and that at the deep lateral sulcus. The anterior margin of the meros-joint in the external maxillipeds is oblique and the external angle obtuse. Chelipeds small, angular, but with smooth surfaces; carpus protuberant and with a strong superior tooth; hand without teeth; fingers compressed nearly as long as the palm. Hair on the outer side of the hand dense, arranged in longitudinal lines. Ambulatory feet of moderate length, fifth pair longer than the fourth. Abdomen of the female with an obtuse carina. On the inferior surface of the body the thick, hairy covering is excavated in numerous pits or concavities, at the bottoms of which the protuberant parts of the abdomen and foot-bases appear, almost bare of pubescence. Color brownish; fingers of chelipeds pale crimson. Length of carapax, 0.37; breadth, 0.35 inch.

In our specimen, which is evidently a young one, the copulatory sulci are indistinct, and produced only to the fifth sternal segment.

It was found among soft sponges dredged in six fathoms, on a muddy bottom, in Port Jackson, Australia.

Genus CRYPTODROMIA Stimpson

This name has been proposed for a group of small species which are very numerous in the East Indian and Pacific seas. They are littoral in their habits, and always found concealed in some foreign living body, generally a compound ascidian. They are easily recognized by their size and aspect, being small, subglobular, and covered with a very short pubescence only. The carapax is generally a little

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CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

broader than long, with a rather broad front. Teeth of antero-lateral margin often bifurcated. Palate armed with a ridge on each side. External maxillipeds as in *Dromia*. Feet as in *Dromia*, but always more or less nodose. Posterior pair longer than the penult pair. The copulatory sulci of the female sternum are remote from each other, and terminate in the fourth segment (that of the second pair of feet), each in a little tubercle. The abdomen is generally armed with nodiform or spiniform projections. The male abdomen is sufficiently broad, with free (unsoldered) segments; appendages to the penult joint conspicuous; terminal joint usually broader than long.

The *Dromia nodipes* of Lamarck and *D. lateralis* of Gray belong to this genus, and perhaps also *D. fallax* and *D. caput-mortuum*. These species have not yet been fully described, however, and in the uncertainty we name as the type *C. coronata*, described below.

278. CRYPTODROMIA CORONATA Stimpson

PLATE XX, FIG. 2

Cryptodromia coronata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 239 [77], 1858.

Carapax broader than long, evenly convex; surface minutely roughened with grains and covered with a very short but strongly adhering pubescence. Front very broad, 5-toothed, teeth large and sharply projecting, subequal; middle one somewhat smaller than the others and placed at a lower level; outer or lateral ones situated on the superior margin of the orbit. The inferior orbital tooth is nearly equal in size to those of the front. External hiatus or notch of orbit not deep; tooth at external angle scarcely prominent. Antero-lateral margin 5-toothed, but with two teeth only showing prominently, the posterior tooth being as small as the angle of the orbit, and the second tooth being at a much lower level than the others, and on the subhepatic region. The two large teeth are slightly bilobed, the anterior lobe in each being a sharp tooth, but the posterior one broadly rounded. Feet nodose; tubercles not very numerous, but prominent; interspaces reticulated. This reticulation is best seen on the outer surface of the hand, which is entirely covered by it. Chelipeds equal. Fingers very strongly gaping, dentate at tips; dactylus slightly compressed, with a broad, deep sulcus on the front or outer surface, and 2–3-dentate on the inner edge toward base. The feet of the last pair are considerably longer than those of the penult pair. Male abdomen rather broad; last joint much broader than

long; penult joint narrower; third and fourth joints each with four spines, the spines short, those of the fourth joint most prominent; a short spine on each side at the posterior angles of the fifth joint. Color lemon-yellow or orange, sometimes blotched with brown on the dorsal aspect. Fingers of chelipeds carmine. Length of carapax in the male, 0.525; breadth, 0.56 inch.

The back was covered by a close-grained sponge.

It was found among madrepores at the depth of a fathom, in Port Lloyd, Bonin Island.

279. CRYPTODROMIA LATERALIS (Gray) Stimpson

PLATE XX, FIG. 3

Dromia lateralis GRAY, Zoölogical Miscellany, p. 40.

Our specimens agree with the description above cited, except in dimensions, which are, according to Gray: "Length, 7; breadth, 6½ lines." In ours the carapax is broader than long. But Gray may have measured the body as protruding beyond the carapax behind.

The front is large, very strongly projecting, and bicuspid. Color uniform, light yellowish-brown.

Found at low-water mark on rocky and stony ground and among sponges, in six fathoms, muddy bottom, Port Jackson, Australia.

280. CRYPTODROMIA TUBERCULATA Stimpson

PLATE XXI, FIG. 6

Cryptodromia tuberculata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 239 [77], 1858.

Carapax broad, smooth, scarcely at all pubescent. Front broad, little prominent, 5-toothed, including the præorbital teeth; teeth subequal, obtuse; median tooth most acute and prominent. Lateral margins 4-toothed; the first two teeth strong and tuberculiform; the third low and elongated, but deeply separated from the second and fourth; the fourth situated at the lateral sulcus. First tooth separated by a considerable interval from the orbital angle. On the subhepatic region there is an arched row of tubercles or teeth extending from the extero-inferior corner of the orbit to the second lateral tooth; these tubercles diminish in size outward; the two nearest the eye are very strongly prominent and are nearly as large as the lateral teeth. There are also two teeth in a transverse row next to the anterior angle of the buccal area. Chelipeds strongly

tuberculated, with conical tubercles; on the carpus there are three or four large and about ten small tubercles. On the hand there are twenty to twenty-five tubercles, variable in size, mostly on the external surface. The inside of the hand is densely pubescent. Fingers in the male gaping, much compressed, and tapering towards the extremities. The first and second pairs of ambulatory feet are sharply verrucose, four or five of these teeth or verrucæ on the superior margin of the carpal joint. Abdomen of the female, with the third, fourth, and fifth joints each armed with four tubercles, two in the middle and one on either side. These tubercles are sometimes seen also in the male abdomen, but less constantly than in the female. The color is much obscured, but appears to be, in living specimens, a dark neutral tint, mottled with greenish; fingers white. Length of carapax in the male, 0.43; breadth, 0.52 inch.

Found at Selio Island in Gaspar Strait, at the Island of Kikaisima, and on the shores of Kagosima Bay. At the latter place it occurred under stones, among boulders, in the middle divisions of the littoral zone.

281. CRYPTODROMIA TUMIDA Stimpson

Cryptodromia tumida STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 240 [78], 1858.

Carapax smooth, short-pubescent, convex, extremely tumid at the gastric and hepatic regions, the dorsum rising abruptly behind the front. The front is like that of *C. tuberculata,* but the lateral teeth (of the three interocular ones) are more prominent than the middle one. Antero-lateral margin with three small equal tuberculiform teeth besides the fourth or usual one at the lateral sulcus, which is much behind the third. One strong tubercle on the subhepatic region in the interval between the orbit and the first lateral tooth. One tubercle at the antero-lateral angle of buccal area. Chelipeds sparsely verrucose; three or four tubercles on the carpus; four on the hand above, two at the base, and two nearly obsolete at the juncture of the dactylus; outer surface of the hand smooth or with some longitudinal lines of obsolete granules. Fingers in the male very much gaping, touching only at the tips; in the females compressed and not gaping. Ambulatory feet of the first and second pairs irregularly protuberant, scarcely verrucose; upper margin of carpal joint on the inner side strongly convex and smooth. Abdomen of both sexes smooth, the tubercles, if any, being obsolete in our specimens. Color in preserved specimens yellowish; fingers crimson at the middle. Length of the carapax in the female, 0.38; breadth, 0.45 inch.

Found in Foukow Bay, on the northwest side of the island of Ousima.

282. CRYPTODROMIA CANALICULATA Stimpson

Cryptodromia canaliculata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 240 [78], 1858.

Carapax convex, uneven, and distinctly channeled parallel to the frontal and antero-lateral margins, the channel being rather broad and rendered more conspicuous by being nearly destitute of the pubescence which covers the rest of the surface. Transverse sulcus deep between the gastric and cardiac regions. Front much projecting; median tooth and the two next prominent, acute; præorbital teeth much smaller and less prominent; external angle of orbit acute. Antero-lateral margin three-toothed, including the posterior or sulcus tooth; the first tooth is much the strongest and sharpest, and between this tooth and the angle of the orbit there is a ridge concave in outline. A strong concavity on the subhepatic region is well circumscribed by this ridge and another ridge, which extends between the strong subhepatic tooth and the second lateral tooth. The suborbital tooth is also very prominent. Feet much pubescent and stout-hairy; chelipeds nearly as in *C. tumida,* but with the longitudinal ridges on outer surface of hand more strongly defined; fingers much compressed. Ambulatory feet of the first and second pairs very angular and subverrucose, but not tuberculated; upper side of carpal joint depressed, almost concave. Abdomen smooth, that of the male with a deep sinus on each side at the penult joint. This species is of a dirty buff color. Length of the carapax in a female, 0.31; breadth, 0.36 inch.

One individual was found carrying upon its back a piece of seaweed (*Padina*); the others all used compound ascidians.

Inhabits rocky shores, among seaweeds, in the lowest division of the littoral zone. Taken in Gaspar Strait by Captain Rodgers; also at Loo Choo and Kikaisima by other members of the expedition.

Genus DROMIA Fabricius

This genus as restricted will contain those species like *D. vulgaris, D. rumphii,* and *D. lator,* in which the palate is smooth, and the sternal sulci of the female are not approximated, and produced only to the fourth sternal segment, between the bases of the second pair of feet. The carapax is transverse, convex, and pilose. The front is rather narrow and prominent. Hepatic regions not excavated. In

the external maxillipeds the palpus is inserted at the internal angle of the meros, the anterior margin of which is consequently transverse. The feet are of moderate size, with the meros-joint not dilated; fingers of the first pair with calcareous apices. The feet of the posterior two pairs are smaller and shorter than the rest, though about equaling each other in length. They have subcheliform extremities, the penult joint being armed with a spiniform process nearly as long as the minute sharp dactylus. The abdomen is unarmed; that of the male is rather narrow, with its penult joint contracted, appendages conspicuous.

The species are of large size, and the adult individuals do not appear to carry about with them any protecting body.

Found in the warmer seas of both oceans. Type, *D. vulgaris.*

283. DROMIA RUMPHII[1] Fabricius

PLATE XXI, FIG. 7

Cancer dromia LINNÆUS (?).
Dromia rumphii FABRICIUS, Suppl., 359. MILNE EDWARDS, Hist. Nat. des Crust., II, 174.

This large species is common on muddy bottoms in from four to ten fathoms in the harbor of Hongkong, China. In one of our specimens, a male, the carapax measures 3.4 inches in length and 4.05 inches in breadth. It is everywhere covered with a thick coat of short dark-brown hairs or bristles. The carapax beneath this coat is reddish. Fingers bare, red.

In De Haan's figure of this species (Fauna Jap., Crust., pl. XXXII) the penult joint of the male abdomen is represented of about the same breadth as the fifth and seventh, while in our examples it is considerably narrower. The first and second ambulatory feet are also shorter than he has figured them.

Genus PSEUDODROMIA Stimpson

The carapax is narrow, much longer than broad, convex, and pubescent. In the specimen upon which the genus is founded the shell is but little indurated posteriorly. The facial region is more than half as wide as the carapax. Front triangular, very prominent, almost rostriform. The epistome or interantennulary triangle is not soldered to the front as in allied genera. Palate armed with

[1] *Dromia dormia* (Linnæus).

ridges. In the external maxillipeds the external angle of the meros is obtusely rounded and the palpus rather large. The feet are similar to those of *Dromia* in character, but those of the fifth pair are of great length, longer than the second pair. For want of female specimens we cannot ascertain the character of the copulatory sulci. The male abdomen is unarmed, elongated, tapering to a point, with its joints all free; appendages of penult joint minute; terminal joint triangular, much longer than broad.

The narrow carapax and very long posterior feet will serve to distinguish this genus.

284. PSEUDODROMIA LATENS Stimpson

PLATE XXI, FIG. 3

Pseudodromia latens STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 240 [78], 1858.

The description is drawn up from a single specimen, a male, perhaps young. The body is mostly covered with a short pubescence, becoming longer, however, on the edges of the feet. The back of the carapax is smooth and glabrous, in some parts nearly destitute of pubescence. Carapax elongated, contracted a little at the lateral sulci and at the facial region and dilated a little near the posterior extremity. Lateral margins smooth, no tooth even at lateral sulcus. Interantennary front very narrow, rostriform, triangular, deflexed; apex obscurely tridentate and setose. A slight angle, but no tooth over eye peduncle, and no tooth on the external or inferior side of the orbit. The hiatus of interantennulary septum is very narrow, but extends all the way back, entirely disjoining the epistome from the front. Chelipeds smooth, rounded; fingers toothed as usual in *Dromiæ,* but very sharp. Ambulatory feet also smooth, their terminal nails very long and sharp. When folded the last pair of feet are thrown forward of the second pair, and reach quite to their extremities. The male abdomen is long and tapering, last joint with acuminated extremity. Color yellowish-white. Length of the carapax, 0.38; breadth, 0.27; length of posterior pair of feet, 0.39 inch.

This animal can draw itself deeply into its thin "jacket" or covering (a compound tunicary), and pucker up the aperture so as to be entirely concealed.

It was dredged in twelve fathoms on a sandy bottom in Simons Bay, Cape of Good Hope.

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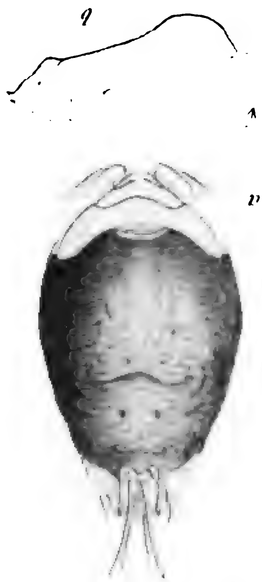

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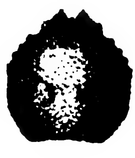

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CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

Genus PETALOMERA Stimpson

The carapax in this genus is oblong or subovate, longer than broad, and with the exception of the epimera well indurated. The epimera, or sides beneath the lateral sulci, are membranaceous, being protected by the expansions of the meros-joints of the feet. The front is prominent and tridentate. Lateral margins convex, with no prominent angle. The facial region is sufficiently broad, with the antennæ closely packed and flattened on their outer sides, showing an even surface. Buccal area rather small, neatly filled by the external maxillipeds, and much broader anteriorly than posteriorly. Palate armed with ridges. Anterior margin of meros-joint of external maxillipeds oblique. The meros-joints of the anterior three pairs of feet are dilated above with rounded lamelliform expansions. The extremities of the fingers of the chelipeds are cochleariform and corneous. The posterior two pairs of feet are much like those of *Dromia*, the last pair longest.

285. PETALOMERA GRANULATA Stimpson

PLATE XXI, FIG. 4

Petalomera granulata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 240 [78], 1858.

Carapax convex, sparsely but conspicuously granulated. The lateral sulcus is situated at the posterior third of the length. Frontal median tooth inferior and very small; lateral ones very prominent; supraorbital tooth small; outer orbital fissure closed. Three small inconspicuous granulated teeth on the antero-lateral margin, between the scarcely prominent orbital angle and the lateral sulcus, the first one subhepatic. A small process on the second joint of the external antennæ. Feet all granulated except the posterior pair, which are smooth. Chelipeds granulated and crested; crest of carpus spinulose; a tubercle at the summit of the carpus and one at that of the hand. The fingers are short, not gaping, with a transverse or oblique ridge on the outer surface defining the corneous tips, and having some resemblance in the side view to the bill of the *Mormon*, or puffin. The superior margin of the lamellar dilatation in the meros-joints of the feet is smooth and sharp. Color in life orange, with reddish clouds. Length of the carapax in the male, 0.36; breadth, 0.33 inch.

Taken from a shelly bottom in twenty fathoms, in Kagosima Bay, Japan.

Genus CONCHŒCETES Stimpson

This genus is founded upon the old *Cancer artificiosus* of Herbst, which, like Guérin's *Hypoconcha,* uses a valve of the shell of some acephalous mollusk for its transportable covering and hiding place. Its posterior feet present, therefore, modifications specially adapted for securing this kind of habitaculum.

The carapax is depressed, subpentagonal in shape, and nearly naked. The dorsal sulci are conspicuous. Besides the usual sulci arising from postero-lateral notches, there is another, of considerable depth, extending from the antero-lateral corner of the carapax to the transverse gastro-cardiac suture. The front is rather narrow. The palate is armed with ridges. The feet of the fourth pair are robust, thicker than those of the second and third pairs, and nearly as long; the dactylus is large and hook-shaped, recurving upon an obtuse process of the penult joint at its base. The feet of the fifth or last pair are very slender, and their extremities are not subcheliform, having only a minute, somewhat twisted dactylus. Our only female specimen is immature, but the sternal sulci seem to be like those of *Dromia* proper. The male abdomen is of moderate breadth, with the fifth and sixth joints apparently soldered together, although the commissure is distinct; appendages to penult joint rounded; terminal joint subcordate, as broad as long.

The only species known is an inhabitant of the East Indian seas.

286. CONCHŒCETES ARTIFICIOSUS (Herbst) Stimpson

PLATE XXI, FIG. 5

Cancer artificiosus HERBST, Naturg. d. Krabben und Krebse, III, 54, pl. LVIII, fig. 5.

Conchœcetes artificiosus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 240 [78], 1858.

About one inch in length, of a light buff color above, with a little pale red on the posterior part of the carapax; beneath darker; fingers and dactyli of the feet reddish-white. Surface minutely pubescent. It is found in valves of *Cytherea,* etc.

Taken sparingly in eight and ten fathoms on the shelly bottom of the channel between Hongkong Island and the Chinese main.

RANINIDEA

Genus COSMONOTUS White

287. COSMONOTUS GRAYII Adams and White

Cosmonotus grayii ADAMS and WHITE, Voy. Samarang, Crust., p. 60, pl. XIII, fig. 3.

As this curious crustacean is not fully described in the work above cited, some of its more important characters will be noted here. The antennæ are nearly as in *Ranilia.* The eyes are seated at the extremities of very long compressed peduncles, somewhat dilated toward the base, and retractile backward into oblique orbits, reaching to the antero-lateral angles of the carapax at the level of the middle of the outer maxillipeds. The whole outer surface of these maxillipeds is squamose or roughened with arcuated and ciliated lineolæ; but there is no oblique ciliated crest on the ischium, as in *Ranilia* and *Notopus;* meros-joint as long as the ischium; exognath sufficiently broad and reaching a little beyond the tip of the ischium. Sternum, as in *Ranilia,* narrow between the bases of the second pair of feet. Last joint of abdomen in the female free.

The carapax was of a palish brick-red color in life, with a median line of white. Feet and inferior surface white.

Our specimen of this species was caught with the "deep-sea clams" on a sandy bottom in ninety fathoms, off the northeast extremity of Formosa, eighty miles from land.

SCHIZOSOMI

PORCELLANIDEA

Genus PETROLISTHES Stimpson

Carapax depressed, subovate, not broader than long. Front triangular, with a more or less undulated margin, which may be either smooth or dentated. There is often a small tooth or lobe on each side at the base of the triangular main body of the front. Eyes rather large. The coxal joint of antennæ is small, not reaching the superior margin of the carapax, and often concealed beneath the corner of the subhepatic shield, but sometimes its inner angle is exposed in the form of a tooth beneath the eye. The movable part of the antenna is thus not excluded from the orbit, but works freely in

its external hiatus, coming in contact with the eye. The movable peduncle of the antennæ is more or less crested. The epimeral pieces of the carapax are posteriorly continuous and entire. Chelipeds broad and depressed. Dactyli of the ambulatory feet of the normal form—that is, short and robust—without supplementary unguicles.

The name *Pisidia* of Leach can properly be retained neither for *Petrolisthes* nor for *Porcellana* restricted, since Leach's genus was founded upon a purely fanciful character, and about half its species will go in one of those genera and half in the other.

The species of *Petrolisthes* are very numerous, inhabiting the tropical and temperate zones in both oceans. They are strictly littoral in station. The following species, heretofore described, may be classed here, *P. violacea* being considered the type:

Porcellana violacea Guérin.
valida Dana.
rupicola Stimpson.
elongata M. Edw.
japonica De Haan.
asiatica Gray.
polita Gray.
armata Gibbes.
maculata M. Edw.
lamarckii M. Edw.
speciosa Dana.
scabricula Dana.

Porcellana dentata M. Edw.
tomentosa Dana.
boscii Savigny.
galathina Bosc.
hirsuta Gray.
edwardsii De S.
tuberculata Guér.
tuberculifrons M. E. & L.
tuberculosa M. Ed.
acanthophora M. E. & L.
coccinea Owen.

288. PETROLISTHES SPECIOSUS (Dana) Stimpson

PLATE XXII, FIG. 2

Porcellana speciosa DANA, U. S. Expl. Exped., Crust., I, 417, pl. XXVI, fig. 8.

Petrolisthes speciosus STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 241 [79], 1858.

This species in life is of a purplish or reddish-brown color above, with a bluish-white hoariness in old specimens. Beneath deep crimson. It is sometimes found of a much larger size than is mentioned by Dana; thus, in a specimen from Japan, the carapax measures 0.61 inch in length and 0.575 in breadth; the hand 1.05 in length. Most specimens differ somewhat from Dana's figure, as follows: The angles are less rounded and the carpus in the right cheliped has fewer teeth on the anterior margin, is not so closely serrated on the posterior margin, and is more prominent at the external angle.

It is very common on the shores of the Western Pacific, ranging in station from low-water mark to above half-tide level on rocky and stony ground. It was found by us in Kagosima Bay, at the Bonin Islands, at Ousima, and on the outer shore of Hongkong Island.

289. PETROLISTHES PUBESCENS Stimpson

PLATE XXII, FIG. 3

Petrolisthes pubescens STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 241 [79], 1858

The carapax and feet are everywhere pubescent above. The margins of the feet, and particularly the outer margin of the hands, are densely ciliated. Carapax subovate, very slightly longer than broad, sides rounded, and not margined with an elevated line, but armed with a minute spine in the post-orbital sinus. Front somewhat trilobate; median lobe largest, rounded, and sufficiently prominent. Suborbital margin not deeply concave. Basal crest of outer antennæ much projecting. External apex of the ischium in the external maxillipeds not produced. The chelipeds above are nearly smooth beneath the pubescence, but in part minutely and sparsely spinulose; meros spinulose above; front margin of carpus five- or six-toothed, the tooth being alternately large and small, the large ones sometimes denticulated, inner tooth largest, no tooth on the part next the hand; a few spinules along the posterior side of the carpus; outer margin of the hand armed with ten small spines above the marginal series of ciliæ; superior edge of dactylus denticulated. Upper margin of the meros-joint in the ambulatory feet spinulose. Color above bluish-white, distantly and regularly spotted with purplish-brown, the carapax having four spots about the middle and others about the margin; feet each with four or five spots; beneath white. Length of carapax in the male, 0.31; breadth, 0.295; length of larger hand, 0.46; breadth, 0.19 inch.

Very near to *P. tomentosa* Dana (loc. cit., I, 420, pl. XXVI, fig. 10), but the carapax is broader, with a more depressed and even surface; the outer margin of the hand is spinulose along the whole length; the outer maxillipeds are not smooth, but transversely lineolated, and the meros of the ambulatory feet is spinulose above for the whole length.

Found under large stones on the ocean shore of Foukow Bay, Ousima.

290. PETROLISTHES HASTATUS Stimpson

PLATE XXII, FIG. 4

Petrolisthes hastatus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 241 [79], 1858.

Carapax above and posteriorly depressed and smooth, anteriorly and at the sides transversely striolated. Front triangular and prominent, with the longitudinal furrows sufficiently deep. Marginal lines not conspicuous; no spine behind the orbit. Crest of the basal joints of the outer antennæ prominent, bilobate; inner lobe acute, outer one rounded. Chelipeds regularly but not very strongly granulated above; posterior margin of carpus not spinulose, but produced into a rather long, curved spine at its outer extremity; anterior margin of carpus armed with three or four elongated but not very prominent teeth. Ambulatory feet hairy; meros sparsely spinulose above. Outer apex of ischium in the external maxillipeds not produced. Color olive, variable in depth in different individuals, and often minutely mottled with white. Length of carapax in the male, 0.47; breadth, 0.46 inch.

Found in a small harbor at Kikaisima; also at Ousima.

291. PETROLISTHES JAPONICUS (De Haan) Stimpson

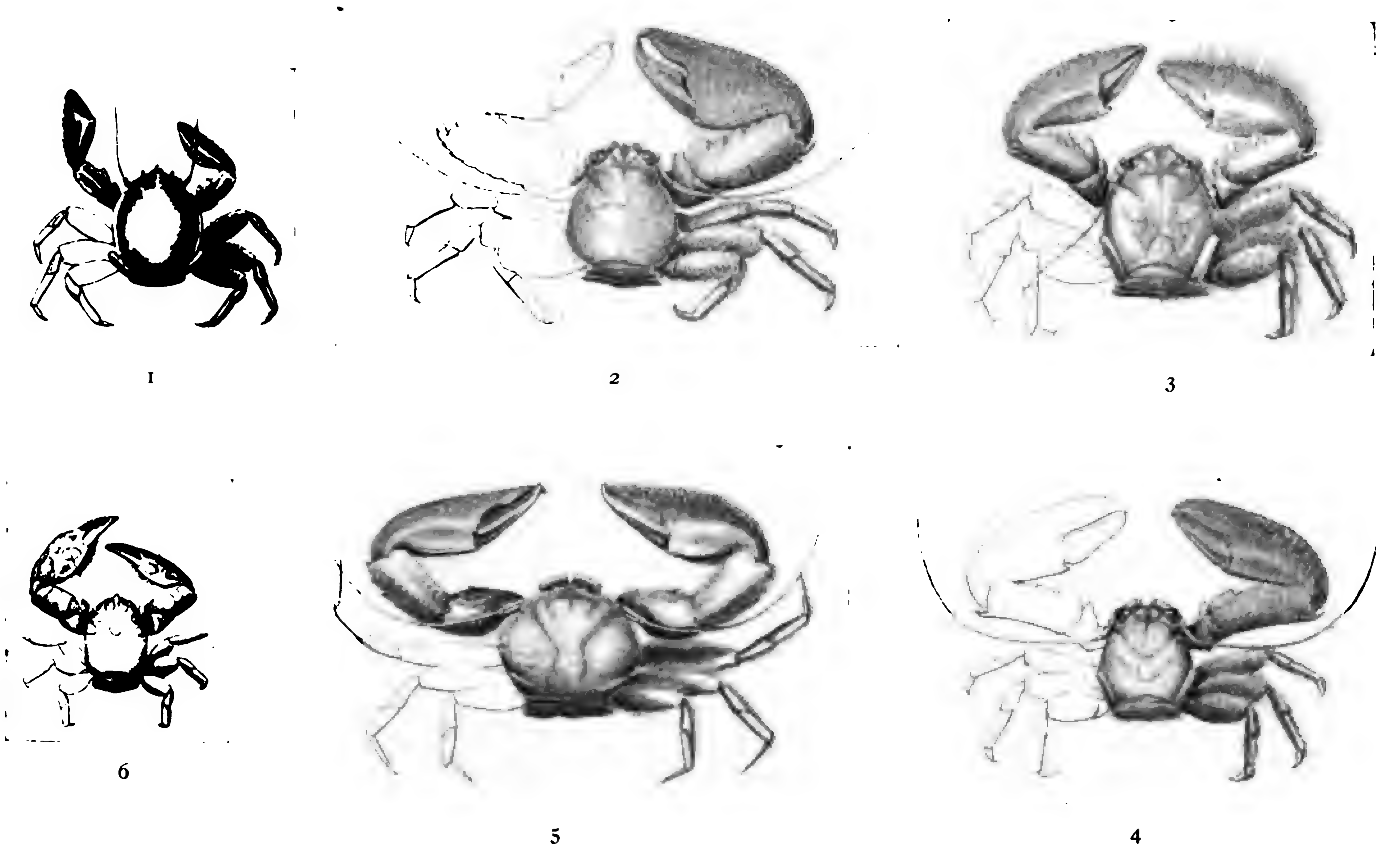
Porcellana japonica DE HAAN, Fauna Japonica, Crust., 199, pl. L, fig. 5.
Petrolisthes japonicus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 241 [79], 1858.

In life this species is of a dark olive color above and bluish-white below.

It inhabits the lower levels of the littoral zone, and occurred at Simoda in Japan, at the Bonin Islands, at Kikaisima, at the Amakirrima Islands, and at Hongkong, in China.

Genus RAPHIDOPUS Stimpson

In this form, so distinct from the ordinary *Porcellanæ*, the carapax is rounded, broader than long, and a little projecting at the sides. The front is transverse, not prominent, and tridentate. The eyes are very small and deep-seated. The first or coxal joint of the external antennæ is very large, joining the superior margin of the carapax, and much produced, far removing the movable portion of the antennæ from the orbit. The external maxillipeds are of the usual form; the ischium, however, is short, very much dilated and



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rounded within, and its external apex is not produced. The chelipeds are not broad and depressed, but thick; the hands are about equal, but not large, so that they do not touch each other when the chelipeds are folded against the face. Finally the dactyli of the ambulatory feet are of a shape remarkably different from anything yet observed in the family; instead of the short, thick, curved form observed in all other genera, we have a straight, slender, elongated terminal joint shaped like a stiletto or a flattened needle, and sharply pointed, but without any indication of a distinct unguiculus. This form of feet is well adapted to the habits of the animal, enabling it to move with facility through the soft mud in which it lives.

It is an inhabitant of moderately deep water, and the only known species is found in the Chinese seas.

2 2. RAPHIDOPUS CILIATUS Stimpson

PLATE XXII, FIG. 5

Raphidopus ciliatus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 241 [79], 1858.

Sides of the body and margins of the feet thickly ciliated with long, fine hairs. Carapax pubescent, somewhat areolated; surface a little uneven, and transversely rugate. Lateral margin strongly convex, with a fissure behind the base of the external antennæ, two small teeth or spines near the middle, and a spine on the postero-lateral margin at the extremity of a short oblique ridge. Frontal teeth minute, the median one most prominent. Anterior margin but slightly sinuated at the orbits. Latero-inferior regions of the carapax strongly striated or longitudinally ridged, especially posteriorly; ridges few in number and subdistant. The external antennæ are four or five times as long as the carapax and folded backwards. Chelipeds large, angular, and very hairy; meros large, more than two-thirds as long as the carpus, roughened above and armed below with a single long, sharp, curved spine; carpus about two-thirds as long as the hand, roughened above, with a median longitudinal spinulated ridge, its anterior margin not dilated, slightly concave and serrulated; its posterior margin convex and armed with five spinules; smaller hand elongated, subtriangular, with three longitudinal obtuse ridges, minutely crenulated or spinulated, on the upper surface; fingers longer than the palm, not gaping, tips much curved, crossing each other, inner edges minutely denticulated but not toothed; inner edge of immovable finger slightly dilated. In the larger hand the dactylus is subcristate above, with a slightly promi-

nent tooth on the crest near the middle, and is armed with a tooth within near the base; the immovable finger bears a strong tooth at the middle of its inner edge. Ambulatory feet long, slender, slightly compressed; meros not dilated; dactyli as long as the penult joint, and slightly sulcated on one side toward extremities; dactylus of last pair of feet shorter than the others. Color white or pale yellowish-brown, obscured by sordes. Length of carapax in the female, 0.3; breadth, 0.39; length of hand, 0.5.

Taken abundantly with the trawl on a muddy bottom in six fathoms, in a bay on the coast of China opposite Hongkong.

Genus PACHYCHELES Stimpson

This genus is readily recognized by its peculiar habit. Its form is less depressed than in *Petrolisthes,* and, while the carapax is smooth, the chelipeds are thick and coarse in appearance, short, and irregularly protuberant or granulated above. The carapax is rounded-ovate, at least as broad as long, with the lateral margins marked by an elevated line, the front somewhat deflexed, a little prominent at the middle, and subacute, but never dentated, with its apex concealed by pubescence. The epimeral pieces of the carapax are not soldered, but separated by membranaceous interspaces, the posterior square piece being particularly well defined. In this latter point this genus differs from all the others of the family. The first joint of the external antennæ is sufficiently well developed in its internal angle, touching, though not joining, the superior margin of the carapax, and excluding the movable portion from the orbit; it is, however, not produced outward or backward, as in *Porcellana* proper and allied genera. The carpus of the chelipeds is remarkably short and broad. Dactyli of the ambulatory feet normal in form.

The genus is littoral in its habits, and is an inhabitant of the temperate and warm-temperate zones in the Pacific and Indian Oceans.

Porcellana grossimana of Guérin may be considered the type of this genus, which also includes the *P. monilifera* of Dana and *P. natalensis* Krauss.

293. PACHYCHELES PECTINICARPUS Stimpson

PLATE XXIII, FIG. 5

Pachycheles pectinicarpus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 242 [80], 1858.

Carapax broad, somewhat depressed in the middle, smooth and glabrous, but obsoletely striated toward the sides. Sinus of the posterior margin very shallow. Protogastric lobules sufficiently

prominent. Front little prominent, pubescent. Chelipeds granulated, not sulcated; larger granules sometimes obscurely arranged in rows; carpus much broader than long, with its anterior margin convex and pectinated with about eight small, equal spiniform teeth. Fingers of the larger hand gaping and pubescent within. This species is of a uniform cream color. Length of the carapax, 0.3; breadth, 0.345; length of greater hand, 0.37; breadth, 0.225 inch.

Found under stones on rocky ground in the third subregion of the littoral zone, on the shore of Ly-i-moon passage, near Hongkong, China.

294. PACHYCHELES STEVENSII Stimpson

PLATE XXIII, FIG. 6

Pachycheles stevensii STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 242 [80], 1858.

Carapax broad-ovate, smooth, not areolated, in the middle glabrous and punctate, at the sides slightly striated transversely, and anteriorly obsoletely granulated. Sinus of the posterior margin shallow, broadly rounded. Front sufficiently prominent, triangular, slightly pubescent. Chelipeds robust, granulated. In the greater cheliped the meros is transversely striated above; the carpus broad and granulated, the granules unequal, the larger ones being sometimes arranged in more or less regular longitudinal rows; anterior margin of the carpus three-toothed, the teeth being prominent, truncated, and denticulated, and the inner tooth bifurcated; hand granulated, granules of the margins very prominent and lobulated; fingers not gaping; immovable finger triangular, a little pubescent within at the base; dactylus with marginal granules less prominent than those of the palm. In the smaller cheliped the anterior margin of the carpus is convex, prominent, and not deeply tridentate; the hand is longitudinally bisulcated on its upper surface, and the fingers are not tomentose. The ambulatory feet are provided with stout, short hairs; dactyli robust, with curved, almost hook-like extremities. Length of the carapax in the female, 0.5; breadth, 0.525; length of greater hand, 0.64; breadth, 0.36 inch.

Found on the west coast of Jesso by Capt. H. K. Stevens, of the steamer "J. Hancock."

Genus PORCELLANA Lamarck restricted

We have restricted the name *Porcellana* to that group which includes most of the old Lamarckian species, and of which *P. platycheles* may be considered the type. The carapax is generally longer

than broad, with the lateral margins more or less acute and projecting, never smoothly rounded. The front is large, prominent, and dentated. The orbits are deep. The first joint of the antennæ is large, joining the superior margin of the carapax, projecting within in the form of a triangular tooth or point, and much produced outward, far removing the movable joints from the orbit. The chelipeds vary in form, being sometimes broad and depressed, and sometimes narrow with a contorted hand; the anterior margin of the short carpus is generally prominent or unilobate next its juncture with the meros. The dactyli of the ambulatory feet are of normal form, but generally rather longer than in allied genera.

A group of small species, with one of the hands much twisted and its fingers excavated, shows some other differences which serve to distinguish it from the typical group founded on the *P. platycheles* and similar forms. They might form a distinct genus (to which the name *Streptochirus* would be applicable), but they are so intimately connected with the others in the more essential characters that it is thought best not to separate them here.

The geographical range of the genus is wide, as it seems to be represented in all seas of the temperate and torrid zones. It is the only genus of its family which occurs in the European waters.

The following known species belong to this genus:

Porcellana platycheles Lamk.
sayii Gray.
pilosa M. Edw.
ocellata Gibbes.
longicornis M. Edw.

Porcellana dehaani Krauss.
armata Dana.
spinifrons M. Edw.
suluensis Dana.

295. PORCELLANA ORNATA Stimpson

Porcellana ornata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 242 [80], 1858.

Carapax subovate; surface anteriorly areolated; protogastric and hepatic lobules particularly prominent. Lateral margins obsoletely 2–3-denticulated. Supraorbital margins deeply excavated. Frontal region with a deep median sulcus. Front with a large median triangular tooth with concave sides; margins minutely serrated or denticulated. Chelipeds moderately broad and flat, nearly equal, sculptured above with ridges, somewhat irregularly tuberculated; beneath obsoletely and distantly squamulated; carpus oblong, quadrate, with two longitudinal granulated ridges on its surface, and with its anterior margin straight and smooth except at its inner extremity, where there is a small denticulated lobe; posterior margin of the

carpus denticulated; hand broad and flat, not twisted, with a rather prominent median ridge and an acute, smooth, ciliated outer margin; fingers short, not gaping; dactylus a little longer than the other finger. Ambulatory feet somewhat hairy. Length of the carapax in the male, 0.26; breadth, 0.235; length of hand, 0.36; breadth, 0.18 inch.

Found at Hongkong, China.

296. PORCELLANA SERRATIFRONS Stimpson

PLATE XXIII, FIG. 2

Porcellana serratifrons STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 242 [80], 1858.

Carapax scarcely convex, nearly smooth, glabrous, occasionally pubescent in parts, anteriorly contracted, posteriorly broadly rounded, and slightly striated towards the sides. Lateral margin acute, turning inwards a little on the surface of the carapax at the lateral notch. There is a small, sharp spiniform tooth at the middle of the lateral margin, and sometimes a minute one in front of it, a spine over the insertion of the external antennæ, and another minute one just behind the external angle of the orbit, which is acute. Beneath this angle there is another spine. Front tridentate; teeth prominent, triangular; middle tooth largest, but not much more prominent than the others; margins minutely serrated. The bases of both pairs of antennæ are spinuligerous. Latero-inferior or epimeral regions of the carapax strongly striated. Outer maxillipeds transversely striated; meros longer than the ischium. Chelipeds of the male glabrous, punctated; angle of the meros prominent, minutely bidentate; carpus three-toothed on each side, with the teeth small, the terminal ones of the series acute; anterior margin of the carpus sometimes five-toothed; hand with the median angular ridge generally little prominent and obtuse; fingers twisted into nearly vertical plane, and pilose within. Smaller hand less twisted than the larger one; its outer margin spinulose; extremity of immovable finger deeply bifid. Hand of the female pubescent externally and with its median ridge tuberculated. Color in life grayish-brown; anterior part of carapax, and sometimes the chelipeds, mottled with dark blood-red. Length of the carapax in the male, 0.32; breadth, 0.32; length of greater hand, 0.53; breadth, 0.19 inch.

Dredged in the circumlittoral zone in the harbor of Hongkong.

297. PORCELLANA DISPAR Stimpson

PLATE XXIII, FIG. 3

Porcellana dispar STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 242 [80], 1858.

Carapax somewhat uneven, but glabrous; sides pubescent; lateral margin acute, forming a prominent angle and turning inward a little just behind the lateral notch, and armed with some minute teeth near the middle; a small tooth or spine above at the insertion of the second joint of the antennæ. Orbital margin less concave than in most species. The front, as seen from above, is straight or slightly convex, but in the front view is seen to be acutely sinuated or deflexed at the middle. Chelipeds very unequal, the greater one with a smooth surface; carpus angular or ridged in the middle and with its anterior margin undulated; hand broad, smooth, not twisted, naked, fingers punctate; dactylus curved, one-toothed within. In the small cheliped the median ridge of the carpus is prominent and its anterior margin bidentate; the hand is very angular, with median ridge acutely prominent, the outer margin pubescent and the fingers twisted into a vertical plane, much curved, excavated and lanose within. Color in life pale brick-red; fingers dark purplish. Length of carapax in the male, 0.24; breadth, 0.22; length of greater hand, 0.38; breadth, 0.18; length of smaller hand, 0.29; breadth, 0.1 inch.

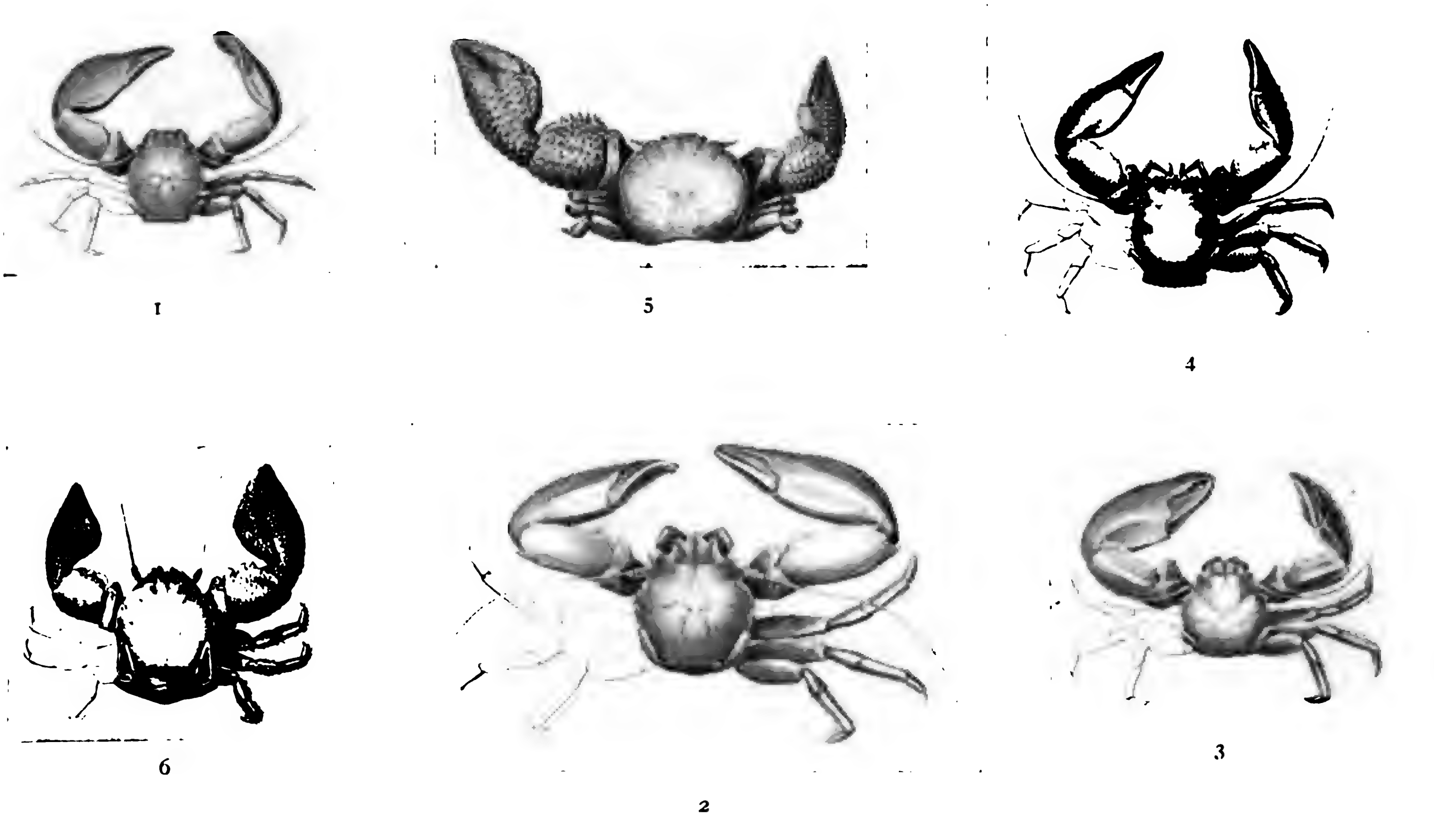
Found under stones in the fourth subregion of the littoral zone at Garden Island, in Port Jackson, Australia.

298. PORCELLANA LATIFRONS Stimpson

PLATE XXIII, FIG. 4

Porcellana latifrons STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 243 [81], 1858.

Carapax subquadrate, longer than broad, slightly convex, smooth; lateral margins acute, but not projecting, and armed with three or four minute spines near the middle, and a larger spine, very sharp and directed forward, above the insertion of the external antennæ. Surface at the frontal region minutely rugate, rugæ transverse. Front very broad, projecting, laminiform, trilobate; median lobe largest, quadridentate, and scarcely more projecting than the lateral lobes, which are bidentate; thus the entire frontal margin is eight-toothed; teeth acute. Eyes large, directed sideways. First joint of external antennæ much produced; flagellum nearly naked. External



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maxillipeds rather long and slender. Chelipeds nearly smooth, minutely reticulated above; carpus large, with the front and back margins each armed with three small teeth; palm of the hand with a row of little spines contiguous to the margin; fingers twisted into an almost vertical plane, and tomentose within; fingers of the larger hand each one-toothed within; those of the smaller hand excavated. The color in life is very variable; it is generally dark greenish, often brownish maculated with white. Length of carapax in the male, 0.25; breadth, 0.22 inch.

This species is very closely allied, if not identical, with the *P. armata* of Dana, 1852 (not of Gibbes, 1850), but appears to differ in its broader front, the middle portion of which is quadridentate and its upper surface not so deeply concave.

Found among net-weed on a sandy bottom in three fathoms, in the strait between the islands Katonaisima and Ousima; also on madrepores taken at one fathom depth on the east side of Hong-kong.

299. PORCELLANA STREPTOCHELES Stimpson

PLATE XXIII, FIG. 1

Porcellana streptocheles STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 243 [81], 1858.

Carapax regularly though very slightly convex; surface glabrous, obsoletely striated, nearly smooth, but scarcely even, the proto-gastric globules being sufficiently prominent. Lateral margin convex, acute, and irregularly denticulated in the middle, two of the little teeth being larger than the rest. The front is neither broad nor prominent, but deeply tridentate; teeth acute; middle tooth deflexed and slightly larger, but no more prominent than the lateral ones, and bearing a slight tooth or angle on each side; lateral teeth sharply triangular. Eyes small. Latero-inferior regions of the carapax longitudinally striated. External maxillipeds slender; ischium small. Chelipeds large, unequal; tooth or summit of meros very prominent; carpus smooth, with the front and back margins each obsoletely 2–3-toothed; smaller hand with a median longitudinal ridge or angular prominence, outer margin obsoletely denticulated, pincers twisted into a vertical plane, broadly excavated and pilose within; extremity of immovable finger emarginated. In the larger hand the dactylus is oblique, shorter than the other finger and bidentate within; immovable finger unidentate within; tips curved. The meros-joints of the ambulatory feet are slender, and almost smooth on the superior margin.

This species, when living, is of a deep blood-red color, which is seen under the lens to consist of crowded dots or punctæ, less numerous on the dorsal surface, where it is consequently lighter. Length of the carapax in the male, 0.23; breadth, 0.215; length of greater hand, 0.39; breadth, 0.16 inch.

This species is common in from six to twelve fathoms on sandy bottoms in Simons Bay, Cape of Good Hope.

It differs from *P. dehaani* Krauss, also from the Cape, in its naked carapax, broader front, with a less prominent median tooth, and non-denticulated superantennary margin.

300. PORCELLANA PULCHRA Stimpson

Plate XXII, Fig. 1

Porcellana pulchra Stimpson, Proc. Acad. Nat. Sci. Phila., x, p. 243 [81], 1858.

Carapax rather convex, with an even surface, apparently smooth, but seen on close examination to be for the most part minutely and closely lineolated in a transverse direction. Lateral margin regularly though slightly convex, expanded with a reflexed laminiform crest. Front very much projecting and laminiform, tridentate; median tooth much the largest, triangular, and acutely pointed; lateral teeth small, acute. External angle of the orbit acute, minutely serrated. Flagellum of external antennæ almost naked, joints oblong. Latero-inferior regions somewhat concave. Chelipeds rather small and slender; angle at summit of meros very prominent; upper surface of carpus and hand with a median longitudinal ridge; a single tooth on the front margin of the carpus; hand triangular, slender at the base, its outer margin nearly straight, acute, ciliated, inner margin forming a ridge continuous with that of the dactylus. Ambulatory feet sparsely provided with plumose setæ; meros minutely serrulated above; dactylus half the length of the penult joint. The meros-joint of the posterior or abnormal feet is short. The colors in life are as follows: Carapax bluish-brown, often with a white median dorsal line; feet brownish clouded, darkest at the middle of each joint; basal joints white. Length of carapax in the female, 0.24; breadth, 0.23. Only two specimens were found, both females.

Dredged from a muddy bottom in six fathoms, in Hongkong Harbor.

Genus PORCELLANELLA White

In the genus for which we have retained the above name, because White's typical species *P. triloba* belongs to it, the body is generally

naked, with a polished and elegantly colored surface. The carapax is considerably longer than broad, with parallel sides. The gastric lobules are not perceptible. The front is horizontal, continuous with the upper surface of the carapax, laminiform, much projecting and tridentate. The external antennæ are similar to those of *Porcellana* proper in the character of the basal joints. The scaphognath of the external maxillipeds is dilated externally at the base, and attenuated toward the extremity. The chelipeds are smooth, with unarmed margins; carpus very short; hand sufficiently elongated. The ambulatory feet are small, with a thick meros-joint and a short, compressed multiunguiculate dactylus.

These animals are parasitic in their habits, the armature of the dactyli of the ambulatory feet enabling them to cling firmly to the zoöphyte upon which they live. This form of dactylus seems to be indicative of a lower grade, being commonly seen in *Galathea* and some Macroura, but never seen among the Brachyura.

The genus inhabits the warm eastern seas, in water of moderate depth.

301. PORCELLANELLA PICTA Stimpson

PLATE XXII, FIG. 6

Porcellanella picta STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 243 [81], 1858.

Carapax oblong, depressed, smooth and even, glabrous, faintly striated anteriorly and at the sides. Lateral margin scarcely acute, but distinct, with the epimeral suture running close beneath it. Front laminiform, tridentate, teeth acute, median tooth much larger and more projecting than the lateral ones. Surface of the frontal region transversely striated. External antennæ more than twice as long as the carapax; coxal joint acutely prominent at its inner angle. Epimera or latero-inferior regions of the carapax obliquely striated. Chelipeds rather slender, sufficiently thick, somewhat rounded, smooth, and glossy like the carapax; anterior angles of ischium and meros produced, acute; carpus small, with smooth margins; hand elongated, contracted at the base, and ornamented within by a line of pubescence extending longitudinally from between the bases of the fingers to the middle of the palm; fingers slender, tapering and irregularly curved, as if distorted; dactylus of larger hand much shorter than the immovable finger. Ambulatory feet small, smooth, glossy, almost naked; inner edge of dactylus armed with four sharp unguicles, the middle one largest. In the terminal joint of the abdo-

men the central triangular piece is small, while the lateral pieces are very large. The color in life is white, with a few large, blue, marginated spots or ocelli on the hands and the anterior portion of the carapax. Length of the carapax in the male, 0.425; breadth, 0.34; length of greater hand, 0.59; breadth, 0.2 inch.

This species is found in considerable numbers hiding between the leaves of the common *Pennatula* on muddy bottoms in six fathoms, in the bays opposite Hongkong, China.

Genus POLYONYX Stimpson

This genus is closely allied to *Megalobrachium* in form and general appearance, but differs in the character of the terminal joints of its feet and its habits. It also resembles *Pisosoma*, but may be distinguished by the enlargement of the coxal joint of the antennæ.

Carapax rounded-oval, as broad as or broader than long, convex, and smooth. Sides strongly convex and obtuse. Front rather narrow, straight, and not prominent. Eyes minute. First joint of antennulæ not toothed, but flattened or truncate at the outer surface. Coxal joint of antennæ as in *Porcellana*, etc., but very much elongated. Chelipeds smooth; meros-joint large. When the chelipeds are folded or retracted the hands do not touch each other. The dactyli of the ambulatory feet are very short and broad, rounded and armed with two or more unguicles on the inner edge.

The typical species of this genus, *P. macrocheles* (Gibbes), is known to be parasitic, living in the tubes of large worms. The habits of the other two species, *P. biungulatus* and *sinensis*, are not certainly known, but are probably similar. They inhabit sandy or muddy places, sometimes above low-water mark, but often in water of considerable depth. Found in the warm parts of both oceans.

302. POLYONYX SINENSIS Stimpson

PLATE XIX, FIG. 5

Polyonyx sinensis STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 244 [82], 1858.

Carapax convex, of a subquadrate form, with the corners rounded: surface smooth, but faintly striated near the margins. Front rather broad, scarcely perceptibly convex. Chelipeds very unequal, smooth, and glossy; in the larger one the meros is more than one-half as large as the carpus, and not dilated anteriorly; carpus almost as long as the hand, with its anterior margin expanded into a laminiform

dilatation, broadest toward the hand; hand thick, short-ciliated exteriorly, and with a few hairs about the middle within; fingers short, slightly unidentate within, tips curved; dactylus shorter than the immovable finger. Ambulatory feet slender, naked; one or two small spinules on the inferior edge of the penult joint; dactyli with one or two minute unguicles besides the principal one. In life this species is of a clear, pale bluish-gray color, with large spots of a neutral tint or sepia color. Length of the carapax in the male, 0.15; breadth, 0.2; length of the larger cheliped, 0.52 inch.

It was dredged from a bottom of shelly sand in twenty-six fathoms, in the China Sea, under the twenty-third parallel of north latitude.

Genus REMIPES Latreille

303. REMIPES TESTUDINARIUS[1] Latreille

PLATE XIX, FIG. 1

Remipes testudinarius LATREILLE, Gen. Crust. et Ins., v, 1, p. 45. MILNE EDWARDS, Illust. Cuv. R. A., Crust., pl. XLII, fig. 1.

Our specimens are broad and depressed, with a single row of ciliated pits or impressed lineolæ along the postero-lateral margin. Color above bluish-gray, minutely clouded; below white. We figure one of our specimens, in order to indicate with more certainty the species we have in hand, which we cannot certainly identify with *R. testudinarius*, a species known to us only from the descriptions and figures of European authors, who do not always agree in their statements with regard to it. The figure in the "Règne Animal," referred to above, is a good representation of the largest of our specimens. But Milne Edwards gives Australia as the habitat of the species.

The expedition specimens were found on the sandy shore of a bay on the eastern side of the island of Ousima.

Genus MASTIGOPUS Stimpson

This genus is remarkable for the form of its anterior feet (for which the name chelipeds would here be inapplicable), which resemble more antennæ than feet, as seen in other genera of Decapoda. It is allied to *Remipes* in form and general character, but the body is more slender. The carapax is elongated and toothed at the

[1] *Hippa adactyla* Fabricius.

antero-lateral margins. The front is tridentate. The antennæ are short, as in *Remipes*. The antennulæ are also short, with the inferior flagellum very small, almost rudimentary. The external maxillipeds are nearly as in *Hippa*, with exarthroid palpus; the apex of the meros-joint is, however, truncated. In the anterior feet the basal or peduncular joints resemble those of *Hippa* and *Remipes*, but the terminal joint is flagelliform—that is, long, slender, and multiarticulate. The ambulatory feet and the abdomen resemble those of *Remipes*, but the external lamella, in the appendages to the penult joint, is much shorter than the internal one.

304. MASTIGOPUS GRACILIS[1] Stimpson

PLATE XXI, FIG. 1

Mastigopus gracilis STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 244 [82], 1858.

Carapax strongly convex in its transverse outline; surface even, but scabrous with asperities, which consist of short transverse impressed lines, minutely setose, and most strongly marked anteriorly. Front with three sharp teeth, median one triangular and nearly as prominent as the lateral ones, which are long, slender, and acute. Antero-lateral margin armed with six subspiniform teeth, the anterior one longest, the rest progressively diminishing. Eyes very long and slender, more than half as long as the antennulæ, which are one-third as long as the carapax. External maxillipeds oblong, nearly rectangular, half as broad as long; their surface flat and nearly smooth, glabrous, with a few scattered punctæ. The basal or peduncular joints of the anterior feet are short, smooth, and nearly naked; penult and antepenult cylindrical; terminal segment or flagellum longer than the carapax, and consisting of twelve elongated joints, with a ring of long setæ at each articulation. Ambulatory feet moderately hairy. Terminal joint of the abdomen lanceolate, thick, with two longitudinal ridges or angles at the base and a deep median sulcus toward the extremity, which is acuminated. The colors in life are as follows: Carapax dark olive, becoming paler at the middle, and brownish at the margins. Front often reddish. A white band crosses the carapax at its posterior extremity. Abdomen bluish, with transverse lead-colored bands at the middle segments. Members all white, with the exception of the external antennæ, which are pale blue. Body beneath, white. Length of the carapax

[1] *Mastigochirus gracilis* Stimpson.

in the male, 0.52; breadth, 0.36; length of the anterior feet, 1.05 inches.

This curious animal was found somewhat abundantly in the sandy bottom of the China Sea, at the depth of twenty fathoms, under the twenty-third parallel of north latitude.[1]

LITHODIDEA

Genus ECHINOCERUS White

306. ECHINOCERUS CIBARIUS [2] White

Echinocerus cibarius WHITE, Proc. Zoöl. Soc., 1848, p. 47, Annulosa, pls. II, III. STIMPSON, Crust. and Echin. Pacific Coast of N. America, p. 36, Bost. Jour. Nat. Hist., VI.

Lopholithodes mandtii BRANDT, Bulletin physico-mathém. de l'Acad. de St. Pétersb., VII, 174.

Specimens of this species were presented to Lieutenant Gibson at Sitka for the expedition.

307. ECHINOCERUS SETIMANUS [3] (Gibbons) Stimpson

Ctenorhinus setimanus GIBBONS, Proc. Cal. Acad. Nat. Sci., I, 48.

Echidnocerus setimanus STIMPSON, Crust. and Echin. Pacific Coast of N. Am., p. 37, Bost. Jour. Nat. Hist., VI.

This species, if distinct, differs from the preceding only in the obtuseness of its dorsal and lateral tubercles.

Two specimens were purchased in the market of San Francisco, Cal. They are obtained rarely in deep water near the Farallone Islands, and so strange are they in appearance that the fishermen always obtain a good price for them as "curiosities."

Genus HAPALOGASTER Brandt

This genus was first instituted by Brandt in the Bulletin of the St. Petersburg Academy for a Sitka species, *H. mertensii*. He does not allude to the *Lomis dentata* of De Haan, which is evidently congeneric. It is distinguished from *Lomis* and *Dermaturus* by the

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[1] 305. HIPPA ANALOGA Stimpson

PLATE XXI, FIG. 2

Not mentioned in the manuscript of this report.

[2] *Lopholithodes mandtii* Brandt.

dilatation of the last two joints of the external maxillipeds. The abdomen, as described for *H. mertensii,* is in some points different from that of *H. dentatus* and *H. cavicauda,* in which two species it is more nearly as described for *Dermaturus.* Although the greater part of the abdomen in the male is soft and coriaceous, yet the segments can be traced, and each segment is indicated by a small, round, indurated piece on each side. The female abdomen is unsymmetrical, as in *Lithodes,* with its segments on the left side a little indurated, corneous, and smooth.

This genus is peculiar to the Northern Pacific Ocean.

308. HAPALOGASTER DENTATA [1] (De Haan) Stimpson

Lomis dentata De Haan, Fauna Japonica, Crust., 219, pl. XLVIII, fig. 2.
Hapalogaster dentata Stimpson, Proc. Acad. Nat. Sci. Phila., x, p. 245 [83], 1858.

The flat lanceolate acicle or movable scale of the external antennæ is regarded as a spine in De Haan's description. The median frontal tooth is subspiniform in the adult, but broader and blunter in the young. The color in life is dark reddish brown.

It is extremely abundant on the shores of Hakodadi Bay, Island of Jesso, inhabiting weedy and stony shores just above low-water mark. It also occurs at Simoda.

PAGURIDEA

Genus CENOBITA Latreille

309. CENOBITA PURPUREA Stimpson

Cenobita purpurea Stimpson, Proc. Acad. Nat. Sci. Phila., x, p. 245 [83], 1858.

Carapax convex, strongly swollen or tumid just behind the front, which is contracted. The surface of the anterior or gastric region is sparsely granulated anteriorly; posteriorly the granules become more numerous, sharp, and setigerous. Branchial regions not much projecting, their lateral margins nearly straight. Eyes much projecting, minutely granulated above, and with the apex sharply projecting, forming a right angle. Ophthalmic scales sharp, not denticulated. Feet moderately hairy on the edges, and thickly hairy below toward their extremities. The upper surfaces of the feet are

[1] *Lomis dentata* De Haan.

mostly smooth and glabrous, except toward their edges and extremities, where they are sharp-granulated or short-spinulose. The larger hand is thus granulated, the granules being very small, with sharp black apices; they are numerous above and on the fingers, but sparsely distributed on the outer surface. The dactyli of the ambulatory feet are spinulose and hairy; those of the right side are somewhat flattened, but not angular. In the third foot of the left side the carpal joint is produced at the inferior angle; and the last two joints are depressed externally, but not flat, and have a smooth punctate surface; the dactylus is convex and spinulose within. The processes from the coxæ of the fifth pair of feet in the male are very much produced, that on the right one being longest and equaling in length the fourth pair of feet.

This species is of a deep purple color, inclining to blue, rarely dark olive. The posterior part of the carapax is lighter, with four longitudinal mahogany-colored stripes, the two inner ones forming a lyre-shaped mark. Teeth of the inner surfaces of the fingers white. Length of the animal, 4 inches; length of the carapax, 1.5; of the gastric or anterior region, 0.96; breadth of the front, 0.31; greatest breadth, across branchial regions, 0.87 inch.

It differs from *C. perlata,* as figured by Milne Edwards in the illustrations to the "Règne Animal," and as described by De Haan, in the smooth external surface of the last two joints of the third foot on the left side, and in its more hairy feet. The apex of the left-hand male organ, or coxal process of the last pair of feet, is scarcely *truncated,* as described by De Haan for *C. perlata,* but is deeply excised on the outer side of the apex, as if a square piece had been cut out.

Found in considerable numbers at the Bonin Islands, on the sides of the hills surrounding Port Lloyd. It was also taken at the Amakirrima Islands by Mr. Squires.

310. CENOBITA RUGOSA Milne Edwards

Cenobita rugosa MILNE EDWARDS, Hist. Nat. des Crust., II, 241. DE HAAN, Fauna Jap., Crust., p. 212. DANA, U. S. Expl. Exped., Crust., I, 471, pl. XXX, fig. 1.

Cenobita clypeata OWEN, Zoöl of Beechey's Voy., p. 85, pl. XXV, fig. 1.

Of an olive color in life. Anterior part of carapax with four brownish spots. A longitudinal median line of brown on the second joint in each foot. The front of the larger hand and the outer surface of the third foot of the left side are pale red.

Taken by us at the Bonin Islands and at Tahiti.

311. CENOBITA CAVIPES Stimpson

Cenobita cavipes STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 245 [83], 1858.

Anterior region of the carapax scarcely longer than the posterior. Branchial regions slightly concave in the lateral margins, but strongly projecting at the posterior angles. Surface of the anterior region almost flattened, smooth and punctate in the middle, but scabrous toward the sides and hairy near the margins. Frontal lateral teeth sharp, apiculated, and placed a little within the lateral extremities of the front. Eyes long, compressed, and scabriculous above; apices bluntly rounded; cornea projecting a little beyond the extremity of the superior process of the peduncle. Ophthalmic scales with acute apices and entire margins. Feet nearly naked, above nearly smooth, but spinulose toward their extremities. Greater hand granulated above and for a short distance on the outer surface, but perfectly polished on the mahogany-colored area below. The granules are white, oblong, flattened, and placed three or four diameters distant from each other; those of the superior margin of the hand are apiculated in black at the distal extremity. Dactylus of the third foot of the right side nearly cylindrical, not at all angular. Third foot of the left side angular; penult joint with its upper surface flat and horizontally dilated outward toward the juncture of the dactylus, forming a prominent ridge, its outer surface anteriorly smooth and a little concave, posteriorly convex and minutely granulated; its lower margin anteriorly convex, posteriorly concave; dactylus quadrangular, on the outer surface smooth, and deeply concave toward the base, above flattened, and within flattened or concave between the ridges, which are spinulose. Posterior coxæ of the male not produced. Length about three inches. Length of the carapax, 0.95; length of gastric region, 0.5; breadth of front, measured between tips of lateral spines, 0.22; greatest breadth, across branchial regions, 0.66 inch.

This is perhaps the same as *C. compressa* De Haan (l. c., p. 213), but the upper and outer surface of the hand is hardly "tenuissime granulato." The lateral margins of the branchial regions are not convex, as described for *C. compressa* of Milne Edwards. From *C. rugosa* it differs in the coxæ of the posterior feet of the male, which are not produced.

Found at Loo Choo, in groves near the seashore, in company with *C. rugosa*.

Genus DIOGENES Dana

We submit the following amended character of this genus:

Ophthalmic ring exposed between the bases of the eye-peduncles, and armed with a bracteole which is often produced and rostriform. Aciculum or basal scale of the external antennæ broad at the base and sometimes bifid; flagellum ciliated. Chelipeds unequal, the left larger, with the commissure between carpus and hand vertical and marginal; hand short and broad, oblique; the fingers oblique, with calcareous, acuminate tips. Dactyli of the second and third pairs of of feet long.

The species are inhabitants of the warmer seas, and are most numerous among the Asiatic islands. The following is a list of the species already known:

D. miles Dana
custos Dana
diaphanus (Fabr.) Stm.
D. spinifrons (De Haan)Stm.
edwardsii (De Haan) Stm.
arenarius (Lucas) Stm.

312. DIOGENES CUSTOS (Fabricius) Dana

Pagurus custos FABRICIUS, MILNE EDWARDS, Hist. Nat. des Crust., II, 236.
Diogenes custos DANA.

Taken at Port Jackson, Australia.

313. DIOGENES BREVIROSTRIS Stimpson

PLATE XIX, FIG. 2

Diogenes brevirostris STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 245 [83], 1858.

Carapax much smoother than in *D. custos,* but somewhat roughened at the sides. Lateral margin of the anterior region armed with five or six spinules. Ophthalmic rostrum smooth, and much shorter than the ophthalmic scales. The eyes, ophthalmic scales, and acicles are nearly like those of *D. edwardsii.* The teeth or points of the frontal margins are all obtuse; the lateral ones most prominent. Great cheliped naked, roughened above with minute subspiniform granules; below glabrous, but obsoletely granulated; superior margin of carpus and hand serrated with small teeth, ten in number, on the carpus; hand with an oblique, infero-posterior crest on the outer surface, armed with seven or eight small spines; inferior margin of hand sharp-granulated; dactylus longitudinally costate above, costæ granulated. Right or smaller cheliped hairy; carpus grooved above.

and with its superior margin armed with sharp spines. Ambulatory feet slender, overreaching the chelipeds; antepenult joint with denticulated margin; penult nearly smooth above; dactylus hairy, compressed, and, as usual, sulcated. Length, 1.25; length of carapax, 0.29; breadth of front, 0.135; length of great cheliped, 0.45 inch.

From *D. custos,* which it resembles in the character of the greater cheliped, this species differs in its shorter rostrum and the smooth superior surface of the penult joint of the ambulatory feet.

Dredged in twelve fathoms on a sandy bottom in Simons Bay, Cape of Good Hope.

314. DIOGENES EDWARDSII (De Haan) Stimpson

PLATE XXIV, FIG. 1

Pagurus edwardsii DE HAAN, Fauna Jap., Crust., 211, pl. L, fig. 1.
Diogenes edwardsii STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 246 [84], 1858.

The ophthalmic rostrum is minute and very narrow, scarcely perceptible to the naked eye. The acicle is short, triangular, and spinulose. Genital apertures of the male on the inner surface of the coxæ. In living specimens the carapax was of a pale red color; feet annulated with pale reddish brown; larger hand white; abdomen yellow, with pale-red sides. Our largest specimen is one and one-half inches in length.

In De Haan's figure the dactyli of the ambulatory feet are represented too short and very much too broad; they are in reality very long and slender, one-half longer than the penult joint.

In this species we have another instance of the economic relation which we so often see existing between a crustacean and a polyp. Upon the outer surface of the greater hand, in all the specimens we have seen, there is seated a small species of actinian. That this is not accidental, we infer, not only from the occurrence of the polyp upon all our specimens of the crab, and its non-occurrence elsewhere, but from the fact that there is a special adaptation of the outer surface of the hand to receive such a parasite; it has a smooth, oval area occupying two-thirds of the surface, and partly surrounded by an elevated ridge. The polyp undoubtedly derives much advantage from this position, so near the food-seizing members of the crab—certainly enough to compensate for any hard knocks its tough body may receive; but what advantage may inure to the crab is here less perceptible than in the case of *Cancrisocia* and *Dorippe*. The surface of the claw to which the polyp is at-

tached appears to be as hard as the rest, and in no need of extraneous protection.

This species is not uncommon in the China Sea, beneath the twenty-third parallel of north latitude, where we obtained several from a sandy bottom in twenty to thirty fathoms. It also occurred at Hongkong.

315. DIOGENES PENICILLATUS Stimpson

Diogenes penicillatus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 246 [84], 1858.

Anterior part of the carapax smooth in the middle, but toward the sides roughened with irregular scale-like projections, the edges of which are serrated and minutely setose. Lateral teeth or points of the front acuminate, and more prominent than the middle one, which is obtusely rounded. The movable or ophthalmic rostrum is small, spiniform, and very acute, reaching scarcely to the extremity of the ophthalmic scales. Eyes in length equaling about two-thirds the width of the front, reaching a little beyond the extremity of the penult joint of the peduncle of the antennæ, and much beyond the acicle; cornea not dilated. Ophthalmic scales broad, with the external margin arcuated, and the apex 2–3-spinulose. Acicle elongate-triangular, armed on the inner side with six or seven aculeiform spines. Flagellum of the antennæ ciliated below. Left cheliped stout and broad, shaped much as in *D. edwardsii,* and shorter than the ambulatory feet; all three edges of the meros-joint crenulated; carpus and hand sharp-granulated on the outer surface, and covered with flattened granules on the inner surface; carpus armed with a spine at the superior and one at the inferior apex, and with its upper margin 10–12-denticulated; hand oblique, with two parallel rows of small teeth or spines above, one at the margin, the other just below it on the outer surface. The outer or perpendicular surface of the hand is thickly penicillate with fine silky hair, equaling in length about the thickness of the hand, the penicillated area being defined posteriorly by a transverse spinous crest, which separates it from a smooth, naked groove at the juncture of the carpus. The dactylus of this cheliped is like the hand, armed with short spines on its superior edge. The length of the animal is about 1 inch; length of carapax, 0.26; breadth of front, 0.13; length of great cheliped, 0.34 inch.

It was dredged from a sandy bottom in thirty fathoms off the east coast of Niphon, in latitude 38° N.

Genus PAGURUS Fabricius

To this genus we assign the following characters: Front without any tooth or point at the middle. Ophthalmic ring exposed between the bases of the eyes, and bearing a bracteole. Eyes more or less thick; ophthalmic scales with broad apices. Aciculum of the antennæ short and stout; flagellum long, naked. Chelipeds unequal, the left largest; hinges of the hand marginal; fingers moving in a vertical plane, and with corneous, somewhat excavated apices.

This genus belongs to the tropical and subtropical seas of both oceans. The following is a list of the species already known:

Pagurus punctulatus Oliv.
spinimanus M. Edw.
affinis M. Edw.
guttatus Oliv.
setifer M. Edw.
euopsis Dana.
fabimanus Dana.
scabrimanus Dana.
difformis M. Edw.
asperus Berthold.
gemmatus M. Edw.
impressus De Haan.

Pagurus pedunculatus Herbst.
carinatus Randall.
asper De Haan
cavipes White.
venosus M. Edw.
sinistripes Stm.
callidus Roux.
striatus Latr.
imbricatus M. Edw.
strigimanus White.
ornatus Roux.
scutellatus M. Edw.

316. PAGURUS ASPER[1] De Haan

Pagurus asper DE HAAN (non MILNE EDWARDS), Fauna Jap., Crust., 208, pl. XLIX, fig. 4 (1850). DANA, U. S. Expl. Exped., Crust., I, 450.

This species, when alive, was of a slag-red or light brick-red color; eye-peduncles with a white ring around the base of the cornea, which shows a reflected blue crescent at the summit in some lights.

De Haan's *P. asper* was published about two years after that of Milne Edwards, but we forbear to change the name, as the latter is a *Clibanarius*.

Our specimens were found on stony ground just above low-water mark, at the island of Ousima.

317. PAGURUS DIFFORMIS[2] Milne Edwards

Pagurus deformis MILNE EDWARDS, An. Sci. Nat. 2d Ser., VI, 272, pl. XIII, fig. 4; Hist. Nat. des Crust., II, 222.
Pagurus difformis DANA, loc. cit., I, 449.

Found at Ousima.

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[1] *Dardanus haanii* Rathbun.

[2] *Dardanus pedunculatus* (Herbst).

318. PAGURUS SCULPTIPES[1] Stimpson

Pagurus sculptipes STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 246 [84], 1858.

Carapax anteriorly naked and glabrous, marked nearly as in *P. punctulatus*. The lateral triangular points of the front (those between the bases of the eyes and antennæ) are rather strongly prominent. Eye-peduncles equaling the anterior margin of the carapax in length, but a little shorter than the third joint of the antennulæ. Ophthalmic scales large, with four minute equal spiniform teeth near the apex. Peduncle of the antennæ shorter than the eyes; acicle small and slender. Feet spinulose or granulose above, and moderately invested with long hair. Left cheliped rather short, a little overreaching the penult joint of the first ambulatory feet, its margins regularly crenulated; lower surface smooth. In the left-hand foot of the third pair the last two joints are broad and deeply excavated on the outer side, with crenulated and thickly ciliated margins, and a median longitudinal ridge, the surface near the superior margin and between the median ridge and the lower margin being elegantly sculptured with transverse striæ or impressed lines corresponding to the crenulations of the edges. General length in a male specimen, 1.5; length of carapax, 0.34; breadth of front, 0.165 inch.

It has the general appearance of *P. punctulatus* and the concave left foot of *P. setifer*. The concavity of the foot, however, is in the latter species smooth.

It was found in Kagosima Bay, Japan.

319. PAGURUS PUNCTULATUS[2] Olivier

Pagurus punctulatus OLIVIER, Encyc. Méth., VIII, 641. MILNE EDWARDS, Hist. Nat. des Crust., II, 222. DANA, U. S. Expl. Exp., Crust., I, 451, pl. XXVIII, fig. 4.

Color in life deep red (carapax orange), everywhere sparsely covered with blue dots or small round spots.

Found on the reefs at low-water mark at Loo Choo; also taken in Gaspar Straits by Mr. L. M. Squires.

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[1] *Dardanus sculptipes* (Stimpson).

[2] *Dardanus megistos* (Herbst).

320. PAGURUS STRIATUS [1] Latreille

Pagurus striatus LATREILLE, Hist. des Crust., VI, 163. MILNE EDWARDS, Hist. Nat. des Crust., II, 218.

If this be the *Cancer arrosor* of Herbst, which is quoted for it by all European authors, we are at a loss to know why that name is not adopted.

Found in a *Cassis sulcosa* taken off the south side of Madeira, near Funchal, in thirty fathoms.

321. PAGURUS PLATYTHORAX [2] Stimpson

Pagurus platythorax STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 246 [84], 1858.

Body much depressed. Carapax above naked, smooth, and glossy. Eyes large, reaching beyond the tips of the peduncles of the antennæ and antennulæ. Ophthalmic scales with a tooth on the inner margin near the base; apex bidentate. Acicle very small. External maxillipeds slender, somewhat flattened, a little separated at their bases, which are exposed, their attachment to the triangular offset forming the apex of the sternum being distinctly visible, not contracted inward and concealed as in other species; exognath slender. Feet coarsely hairy. Chelipeds small, equal; carpus and hand not spinulose, but roughened above and externally at the bases of the hairs. Ambulatory feet depressed, not spinous. Genital aperture of the male on the inner slope of the coxa, and not fringed. Sternum broad, flat, triangular, and broadly exposed between the chelipeds; no suture between the segments corresponding to the chelipeds and the first ambulatory feet. Terminal lobes of the caudal segment equal. General length, 1.4; length of carapax, 0.32; breadth of front, 0.28; length of chelipeds, 0.45; length of eye, 0.17 inch.

This species is always found in a cone or strombus, its depressed form being a special adaptation for the occupation of the narrow cavities of such shells. The remarkable characters of the sternum, etc., result directly from the form of the body, and the general widening of its parts, and cannot be considered as of generic value, particularly as all that set of characters upon which the genera are based in the family are those of the true *Pagurus*.

Pagurus platythorax is allied to *P. fabimanus* and *P. scabrimanus*,

[1] *Dardanus arrosor* (Herbst).

[2] *Dardanus platythorax* (Stimpson).

described by Dana, from the eastern seas. From both these it may be distinguished by its equal hands and broad, flat sternum.

It was found at Loo Choo.

Genus ANICULUS Dana

Front acute at the middle. Ophthalmic ring barely exposed, but protected by a bracteole. Antennæ slender; aciculum short, robust; flagellum naked. Chelipeds very short, equal; commissure of the hand vertical, but with the hinges marginal; fingers moving in a vertical plane, with excavated corneous tips.

This genus is found only in the Pacific and neighboring seas, and is restricted to the torrid and warm-temperate zones. The species are *A. typicus* Dana (*Pagurus aniculus* Fabr.), *A. ursus* (*Pagurus ursus* Oliv.), and *A. elegans* Stm.

322. ANICULUS TYPICUS[1] Dana.

Pagurus aniculus FABRICIUS, Suppl., 411. MILNE EDWARDS, Hist. Nat. des Crust., II, 230. DE HAAN, Fauna Jap., Cr., 209.
Aniculus typicus DANA, U. S. Expl. Exped., Crust., I, 461, pl. XXIX, fig. I.

In our specimen the rostrum is much less acute than in those described by Dana. It was taken at Simoda, Japan.

Genus CALCINUS Dana

Front acute at the middle. Ophthalmic ring concealed. Aciculum of the antennæ short; flagellum naked. Chelipeds unequal, the left larger; commissure of the hand vertical, but with its hinges almost marginal; fingers moving in a vertical plane, and with excavated calcareous apices. Dactyli of the second and third pairs of feet short.

Its geographical range is in the tropical parts of both oceans. The following is a list of the species:

Calcinus tibicen (Herbst) Dana.
chilensis (M. Edw.).
obscurus Stm.
lividus (M. Edw.).
sulcatus (M. Edw.).
Calcinus gaimardii (M. Edw.) Dana.
elegans (M. Edw.) Dana.
latens (Randall) Dana.
cristimanus (M. Edw.).

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[1] *Aniculus aniculus* (Fabricius).

323. CALCINUS TIBICEN[1] (Herbst) Dana

Cancer tibicen HERBST, Naturg. d. Krabben u. Krebse, II, 25, pl. XXIII, fig. 7.
Pagurus tibicen LATREILLE, MILNE EDWARDS, Règne Anim., Crust., pl. XLIV, fig. 3.
Calcinus tibicen DANA, U. S. Expl. Exped., Crust., I, 457.

The colors in life are as follows: Antennæ bright red. Antennulæ, eyes, and ophthalmic scales blue. Carapax bluish-gray. Feet purplish-brown. Hands tipped with white, the larger one more than half white. Ambulatory feet annulated with white near their extremities; two joints near the base with a longitudinal red stripe. In a variety from Ousima the large hand was wholly white.

It is a common littoral species everywhere in the middle and western Pacific. Found by us at the Bonins, at Loo Choo, and at Ousima.

324. CALCINUS LATENS (Randall) Dana

Pagurus latens RANDALL, Jour. Acad. Nat. Sci. Phila., VIII, 135.
Calcinus latens DANA, U. S. Expl. Exped., Crust., I, 459, pl. XXVIII, fig. 11.

Found at Loo Choo.

325. CALCINUS ELEGANS (Milne Edwards) Dana

Pagurus elegans MILNE EDWARDS, Hist. Nat. des Crust., II, 229.
Pagurus pictus OWEN, Beechey's Voy. Zoöl., p. 83, pl. XXV, fig. 2.
Pagurus decorus RANDALL, Jour. Acad. Nat. Sci. Phila., VIII, 135.
Calcinus elegans DANA, U. S. Expl. Exped., Crust., I, 458, pl. XXVIII, fig. 10.

Characterized by its fine coloration, the tuberculated fingers, and the thick brushes on the under sides of the third pair of feet near their extremities, which are very conspicuous in fresh specimens.

Genus CLIBANARIUS Dana

Front acute at the middle. Ophthalmic ring concealed. Eyes long. Aciculum stout. Chelipeds similar in form and subequal; commissure of the hand vertical, with the hinges median, not marginal; fingers moving in a horizontal plane, with excavated corneous apices.

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[1] *Calcinus lævimanus* (Randall).

Its geographical range is in the warm temperate and tropical parts of both oceans. The species are as follows:

Clibanarius vulgaris Dana	*Clibanarius tæniatus* (M. Edw.).
oculatus (M. Edw.).	*cruentatus* (M. Edw.).
crassimanus (M. Edw.).	*aculeatus* (M. Edw.).
tuberculosus (M. Edw.).	*elongatus* (M. Edw.).
tricolor (Gibbes).	*asper* (M. Edw.).
lineatus (M. Edw.) Dana.	*æquabilis* Dana.
striolatus Dana.	*zebra* Dana.
nigritarsis (Lucas).	*virescens* (Krauss) Dana.
vittatus (Bosc).	*brasiliensis* Dana.
panamensis Stm.	*antillensis* Stm.
sclopetarius (Herbst).	*corallinus* (M. Edw.).
longitarsis (De Haan) Dana.	*globosimanus* Dana.
inæqualis (De Haan).	*humilis* Dana.
symmetricus (Randall) Dana.	*pacificus* Stm.

326. CLIBANARIUS LONGITARSIS (De Haan) Dana

Pagurus longitarsis DE HAAN, Fauna Jap., Crust., 211, pl. L, fig. 3.
Clibanarius longitarsis DANA, U. S. Expl. Exped., Crust., I, 464.

This species occurred at Loo Choo.

327. CLIBANARIUS VULGARIS[1] Dana

Cancer clibanarius HERBST, Naturg. der Krabben u. Krebse, II, 20, pl. XXIII, fig. 1.
Pagurus clibanarius LATREILLE, Hist. des Crust. et des Ins., VI, 167.
Clibanarius vulgaris DANA, U. S. Expl. Exped., Crust., I, 462.

The largest of our specimens is three inches in length. The dactyli of the ambulatory feet are considerably longer than the preceding joint, as is represented in Herbst's figure. Milne Edwards, however, in describing this species (Hist. Nat. des Crust., II, 227), says "Tarse court." There is also in our specimens no distinct furrow separating the rostriform tooth from the front, as mentioned by that author. So that it is probable that he had before him a distinct species, and we have therefore not quoted his description.

There is a longitudinal furrow on the outer surface of the dactylus of the third pair of feet. The color of the living animal is a dark purple-brown; back of the carapax dirty whitish. Abdomen dark, with a light-red median line. Peduncles of the eye with two longitudinal white vittæ. Hands with minute white spots on a dark ground. Feet with three white or light-red vittæ, the two outer vittæ diverging from the base of the superior one.

[1] *Clibanarius clibanarius* (Herbst).

Our specimens were found in dead shells of a thick, short strombus. When alive they had a peculiar strong odor, exactly like that of ripe cocoanut milk.

They were found in Hongkong Harbor, on a muddy bottom, in four fathoms; also in Gaspar Straits.

328. CLIBANARIUS STRIOLATUS Dana

Clibanarius striolatus DANA, U. S. Expl. Exped., Crust., I, 463, pl. XXIX, fig. 3.

The following is a description of some specimens, which we find by comparison to be the same as Dana's: Carapax rather narrow, and convex anteriorly. Front with a post-marginal furrow. Ocular peduncles very long, as long as or longer than the anterior region of the carapax, and overreaching the third joint of antennulæ. Ophthalmic scales triangular, deeply notched exteriorly near the apex, and provided with several long, stout hairs. Hands equal, somewhat spinous, and very hairy above; five strong spines on the superior margin of the palm. Ambulatory feet longitudinally vittate, with six red stripes (counted on the penult joint), narrower than their interspaces. Dactyli very slender, in length just equaling the penult joint. Length one and a half inches. Length of the carapax along the median line, 0.525; breadth of anterior extremity, 0.225 inch.

Found at Loo Choo.

329. CLIBANARIUS GLOBOSOMANUS[1] Dana

Clibanarius globoso-manus DANA, Proc. Acad. Nat. Sci. Phila., V, 271.
Clibanarius corallinus? DANA, U. S. Expl. Exped., Crust., I, 468, pl. XXIX, fig. 8.

We prefer to retain Professor Dana's name for this species until opportunities occur for a more certain identification of it with M. Edwards's *corallinus*.

It is abundant on the reefs at Loo Choo.

330. CLIBANARIUS ÆQUABILIS Dana

Clibanarius æquabilis DANA, U. S. Expl. Exped., Crust., I, 464, pl. XXIX, fig. 4.

In small shells dredged in from twelve to twenty fathoms, sandy bottom, in Funchal Bay, Madeira.

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[1] *Clibanarius corallinus* (Milne Edwards).

331. CLIBANARIUS PACIFICUS Stimpson

Clibanarius pacificus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 247 [85], 1858.

This species approaches so closely to *C. æquabilis* that a long examination was necessary before any specific difference was apparent. The feet are, however, more hairy than in that species, the dactyli of the ambulatory feet are somewhat longer, and the lower surfaces of the hands generally smoother. When the hands differ in size, as they sometimes do slightly, the right is generally the larger. Our species is of a very dark bluish-olive color; ambulatory feet bright yellow; fingers of the hand red. It is littoral, and thus differs much both in color and station from *C. æquabilis*. Our largest specimen is a male, one and a quarter inches in length. The length of the carapax in the median line is 0.39; breadth of front, 0.16 inch.

It differs from *Pagurus inæqualis* De Haan in its equal and more spinous hands.

Found among rocks in the lowest subregion of the littoral zone at Tanega-sima and Ousima.

Genus PAGURISTES Dana

It is remarkable that a form so distinct as *Paguristes* should have been so long suffered to remain in the old genus *Pagurus*, while the peculiarities of its external generative apparatus, in both male and female, were well known. We have here the only hermit crab in which the first two pairs of abdominal members are developed into organs subservient to generation. In the male these are adapted to the purposes of generation, as in the Brachyura, though their form is more like those of *Astacus*, and they have a similar position on the lower surface of the abdomen near its base. In the female the anterior pair of appendages is small and situated at the base of the abdomen, and there is a broad, oblique expansion or sac on the left side of its soft body formed by a folding of the integument at the posterior margin of the fourth segment, enclosing a pouch which serves to contain the eggs.

The other essential characters of the genus may be stated as follows: Eyes long. Antennæ short; acicle robust. Chelipeds similar in shape and generally subequal; commissure of the hand vertical; fingers moving in a horizontal plane. Feet of the fourth pair not subcheliform.

It has a wide geographical distribution, species being found in all

seas except those of the frigid and subfrigid zones. The species already known are as follows:

Paguristes hirtus Dana.	*Paguristes gonagrus* (M. Edw.).
tomentosus (M. Edw.).	*pilosus* (M. Edw.).
turgidus Stm.	*frontalis* (M. Edw.).
weddelli (M. Edw.).	*longirostris* Dana.
maculatus (Risso.).	*brevicornis* (Guérin).
gamianus (M. Edw.).	*depressus* Stm.
setosus (M. Edw.).	

332. PAGURISTES DIGITALIS Stimpson

PLATE XXV, FIG. 1

Paguristes digitalis STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 247 [85], 1858.

The carapax is nearly naked about the middle. It is narrowed before and somewhat dilated behind. The cardiac scutella or indurated median plate of the posterior part is somewhat halberd-shaped, being narrowed at the middle and a little widened toward its pointed extremity. The sides of the anterior portion of the carapax are more deeply sinuated than in most species. The rostriform point of the front is elongated, and very sharp, reaching a little beyond the bases of the ophthalmic scales, and carinated along the middle. Eyes very long and slender, slightly longer than the front, and not quite reaching to the extremity of the peduncle of the antennulæ; peduncle naked, excepting a slight tuft of setæ at the superior base. Apex of the ophthalmic scale short, acute, with one denticle on the outer margin. The outer maxillipeds are long, reaching beyond the eyes. Chelipeds equal, resembling much those of *P. hirtus, turgidus*, etc., in character, the carpus and hand being spinous and hairy above, the spines rather numerous, with black corneous tips; hand rather broad and flattened above, with immovable finger depressed; inner edges of the fingers corneous for the terminal half of their length; dactylus angular, with the outer surface flat, elegantly and minutely sculptured with oblique pectiniform crests about seven in number. Posterior feet hairy; those of the second pair spinous above, with the dactylus more than one-half longer than the preceding joint. The dorsal integument of the male abdomen is considerably indurated, forming a thin, flexible plate to each segment; posterior angle of that covering the second segment much projecting and overlapping the third. Lobes of the terminal segment almost symmetrical in both male and female. The callous areolæ forming the "chafing gear" on the inferior surfaces of the thorax and feet are

less well marked than in *P. turgidus*. The color of the animal, in alcoholic specimens, is light brick-red; in parts whitish; eye peduncles with a red vitta. Length, three inches; length of carapax in the male, 0.81; breadth of the front, 0.4; length of cheliped, 1.17 inches.

Found at Hakodadi, on the island of Jesso. It much resembles *P. turgidus* from the opposite coast of the Pacific, from which it may be distinguished by the sculptured surface of the movable finger of the hand.

333. PAGURISTES SEMINUDUS Stimpson

Paguristes seminudus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 247 [85], 1858.

The carapax, front, eye-peduncles, and antennæ in this species are naked, or nearly so. Anterior region of the carapax rather large, much longer than the posterior, with a punctate surface, and armed with a few minute spines at the sides. Median plate or cardiac scutella of the posterior region rather short, somewhat contracted near the base, and blunt at the posterior extremity. Rostrum long and slender, tapering, with its very sharp extremity curving downward and reaching beyond the middle of the ophthalmic scales. Frontal sinuses very deep for the reception of the bases of the eye peduncles. Eyes very stout for the genus, but long, considerably longer than the front is wide, and much overreaching the peduncle of the antennulæ. Apex of the ophthalmic scale slender, very sharp, curving outward; margins entire, smooth, and naked. Antennæ shorter than the carapax; flagellum sparsely provided with fine, short hairs; acicle large and nearly naked, reaching to middle of eye-peduncles. Outer maxillipeds not reaching to the extremities of the eyes. Chelipeds similar in form, but unequal (the left larger); carpus and hand densely hairy and spinulose, spines small, calcareous, those of the superior edge largest; fingers naked above, but hairy exteriorly, and armed within with sharp cutting edges for their whole length; apices acute, black; inferior side of hand tumid, minutely and sparsely subspinulose. Ambulatory feet rather slender; penult and antepenult joints spinous above; dactyli above and on the lower inner edge hairy. Fourth pair of feet rather long, with the scabrous surface on the penult joint very small. No chafing disks or areolæ on the lower surface of the body or feet. Terminal segment of abdomen much elongated; left lobe most produced. Color olive or brownish; antennæ annulated; maxillipeds spotted with white; tips of all the feet white. Length, 1.78; length of cara-

pax, 0.44; breadth of front, 0.22; length of eye, 0.23; of cheliped, 0.7 inch.

Found on rocky shores at half-tide, in Kagosima Bay, Japan.

Genus SPIROPAGURUS Stimpson

Carapax depressed, anteriorly sufficiently indurated, but posteriorly membranaceous, the cardiaco-branchial sutures being, however, strengthened by linear corneous strips. Eyes short, with the cornea dilated. Antennæ large; acicle slender from its base. Left virgula or genital organ of the left coxa of the fifth pair of feet in the male, persistently exserted to a considerable length, slender, compressed, spiral, and membranaceous, with the superior margin strengthened by a corneous strip. Last segment of the abdomen bifid at the extremity; margins of the forks serrated.

In most characters besides those mentioned in the above description this genus agrees with *Eupagurus,* the maxillipeds being remote at base, with small coxæ; the chelipeds more or less unequal, with the right one largest, and the fourth pair of feet scarcely subcheliform, sometimes nearly simple, with compressed dactylus. Its most remarkable characteristic is seen in the exserted left genital organ of the male, forming a "spire" or coil of one or two turns. Something of this kind is seen in some *Cenobitæ,* in which, however, the coxæ are produced on both sides, although to a different length, and indurated.

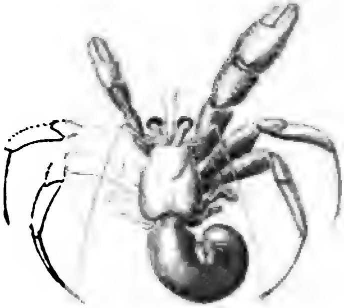
The genus was founded upon the *Pagurus spiriger* of De Haan, which was, until recently, the only known species. The Leyden carcinologist mentions the "spire," but has not, apparently, recognized its identity with the male genital organ.

Only one other species is known, *S. dispar* Stm., which inhabits the Caribbean Sea.

334. SPIROPAGURUS SPIRIGER (De Haan) Stimpson

Pagurus spiriger De Haan, Fauna Japonica, Crust., 206, pl. XLIX, fig. 2.
Spiropagurus spiriger Stimpson, Proc. Acad. Nat. Sci. Phila., x, p. 248 [86], 1858.

The following specific characters may be mentioned in addition to those given by De Haan: The median and lateral points of the front are obtuse. Posterior part of the carapax longer than the anterior part and lineolated or squamose in appearance; squamæ minutely crenulated. Ophthalmic scales large, broad, and obtuse. Flagella of the antennæ almost entirely naked, and overreaching the ambu-



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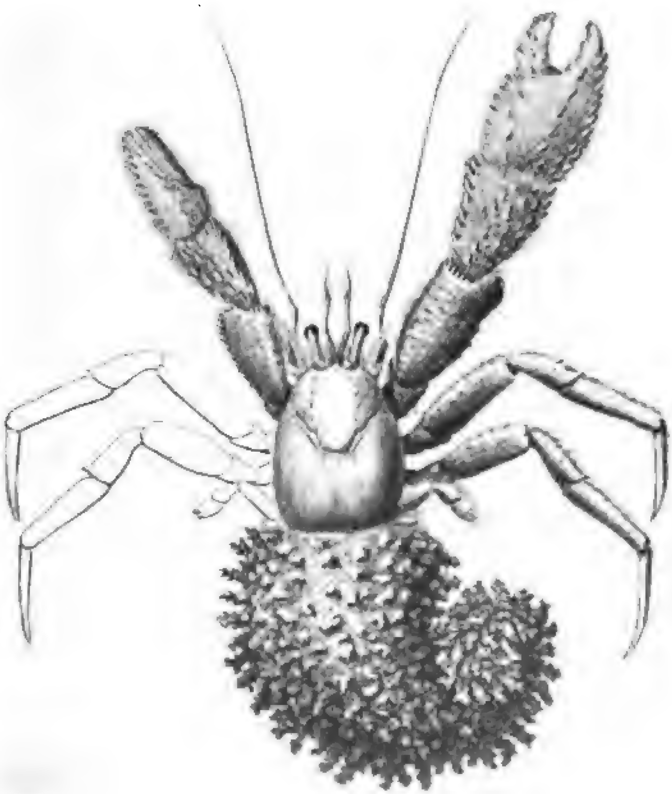


3

CRABS OF THE NORTH PACIFIC EXPLORING EXPEDITION

latory feet. Fingers of the hands slender, with acute margins microscopically pectinated with short setæ; margin of immovable finger also armed with eight minute distant teeth; that of movable finger smooth. Dactyli of the ambulatory feet very long and compressed, adapted for swimming. The animal is of a pale fawn color when alive; sometimes slightly reddish.

This species swims freely, even carrying its shell, by striking the water with its ciliated feet. Our specimens were taken from a muddy bottom in sixteen fathoms off the Chinese coast near Hongkong.

Genus EUPAGURUS Brandt (emended)

In this genus and *Spiropagurus* we find a character of the external maxillipeds which seems to be of considerable importance, although overlooked by those who have previously written upon the family of Paguridæ. In all other genera these maxillipeds are closely approximated at the base, the coxæ being greatly dilated, with their inner surfaces closely applied to each other. In the present genus the coxæ are small, very short, and no larger than the second or basis-joint of the maxilliped, being at the same time widely removed from each other, showing between the prominent margin of the second sternal segment, which is often armed with teeth or spiniform processes. The exognath of the maxillipeds is broader than in the ordinary forms of Paguridæ.

Other characters of *Eupagurus* are the following: Front acute at the middle. Ophthalmic ring exposed, but without a bracteole or indurated plate between the bases of the eyes. Aciculum of the antennæ elongated, slender even from the base; flagellum long. External maxillipeds rather large. Chelipeds dissimilar in form and unequal, the right largest; commissure of the hand horizontal, with the hinges marginal; fingers moving in a horizontal plane. Fourth pair of feet scarcely subcheliform.

This genus inhabits the temperate and frigid zones of both hemispheres. A large number of species is found, both in the North Atlantic and the North Pacific Oceans. In two or three rare instances species occur in the subtropical parts of the Atlantic. The following is a list of the species already known:

Eupagurus bernhardus (Lin.).
ochotensis Brandt.
chiroacanthus (Liljeb.).
forbesi (Bell).
sculptimanus (Lucas).

Eupagurus angulatus (Risso).
meticulosus (Roux).
alatus (Fabr.).
pubescens (Kröyer).
kroyeri Stm.

Eupagurus lævis (Thompson).
hyndmanni (Thompson).
ulidianus (Thompson).
spinimanus (Lucas).
cuanensis (Thompson).
prideauxii (Leach).
brevipes (M. Edw.).
perlatus (M. Edw.).
obesicarpus (Dana).
gayi (Nicolet).
villosus (Nicolet).
forceps (M. Edw.).
truncatulus (Raf.).
mertensii Brandt.
splendescens (Owen).
Eupagurus hirsutiusculus (Dana).
samuelis Stm.
granosimanus Stm.
scabriculus (Dana).
middendorffii Brandt.
conformis (De Haan).
cristatus (M. Edw.).
novi-zelandiæ (Dana).
tenuimanus (Dana).
criniticornis (Dana).
operculatus Stm.
brevidactylus Stm.
pollicaris (Say).
comptus (White).
rubro-vittatus (Lucas).

335. EUPAGURUS MEGALOPS[1] Stimpson

PLATE XXIV, FIG. 2

Eupagurus megalops STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 248 [86], 1858.

Carapax naked; anterior region smooth, glossy, and flattened. Median lobe or tooth of front broad, obtuse, and less prominent than the lateral teeth. Eyes rather remote from each other, shorter than the peduncle of the antennæ by one-third the length of the latter, and with the cornea greatly swollen, so that its diameter is nearly twice that of the peduncle at its base. The acicle of the antennæ is slender from its base, slightly ciliated, and reaches the extremity of the eye; the flagellum is naked, and reaches beyond the ambulatory feet for a fourth of its length. Chelipeds ciliated on the margins; the right one a little shorter than (that is, overreached by) the ambulatory feet; carpus oblong, one-half longer than broad, above sharp-granulous and setose, the setæ short and arising from the anterior bases of the granules; hand broader than carpus, but scarcely more than half as broad as long, tapering and depressed, but convex along the middle; upper surface of the hand roughened with sharp granules smaller than those of the carpus, and very sparsely scattered, there being very few on the convex middle portion of the hand, but more at the sides; fingers hairy, much shorter than the palm, and with calcareous, hooked tips. Left cheliped slender; carpus trigonal, superior keel spinulous and separated by a longitudinal groove from another keel situated to the right and beneath it; hand as long as the carpus of the right cheliped; palm convex and obsoletely

[1] *Pagurus megalops* (Stimpson).

bicarinated, carinæ granulated; fingers elongated, depressed, and somewhat curving downward. The whole upper surface of the hands, excepting the fingers, is sometimes pubescent. Beneath the chelipeds are uniformly and crowdedly granulated, and often pubescent. Ambulatory feet nearly naked; upper surfaces smooth, glossy, and punctate; upper margins spinulose; dactyli contorted, longer than the greater hand, extremely slender, sulcated longitudinally on the inner surface, and ciliated above near their extremities. In the third foot of the right side the penult joint is twice as long as the one preceding it. Length of a male specimen, 1.7; length of carapax, 0.36; breadth of front, 0.2 inch.

This can scarcely be the *Pagurus conformis* of De Haan, who, in his description of the chelipeds of that species, says, "Pedis minoris carpo non spinoso." It is closely allied to *E. gracilipes,* but the eyes are larger and the hands ciliated.

It was dredged from a sandy and shelly bottom at twenty-six fathoms, in the North China Sea, under the twenty-third parallel of latitude.

336. EUPAGURUS GRACILIPES[1] Stimpson

Eupagurus gracilipes STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 248 [86], 1858.

Rostriform point large, strongly prominent, and acute. Eyes very short and thick, shorter than the acicle, and but little over half as long as the peduncle of the antennæ; cornea much inflated; base of the peduncle contracted. Flagellum of the antennæ naked; acicle rather small, with flat upper surface, and both edges somewhat hairy. Right cheliped long and slender, but considerably shorter than the ambulatory feet; carpus oblong, proportion of breadth to length, 1 : 1.5, with the surface subspinulose, as in *E. bernhardus;* hand much depressed, thin, elongated-ovate, half as broad as long, convex in the middle, but concave near the thin margins; nearly smooth above, but sparsely ornamented with minute depressed granules; outer margin of the hand somewhat expanded and crenulated; fingers smooth, depressed, with hooked calcareous tips crossing each other; dactylus carinated at the superior margin. Ambulatory feet as in *E. bernhardus,* but with more slender dactyli. General length, 1.8; length of carapax, 0.35; breadth of front, 0.19 inch.

It differs from *E. splendescens* and *E. mertensii* in the longer ambulatory feet, the terminal joints of which reach much beyond the

[1] *Pagurus gracilipes* (Stimpson).

left hand; from *E. bernhardus* in the shorter eyes, the more elongated and slender feet, and the smoother, flattened hand with lamelliform outer edge.

It was dredged off the east coast of Niphon, in north latitude about 38°, at the depth of thirty fathoms. Found also in Hakodadi Bay.

337. EUPAGURUS OCHOTENSIS[1] Brandt

Pagurus (Eupagurus) bernhardus, var. C, spinimana BRANDT, Sibirische Reise, Zoöl., p. 108.

Pagurus (Eupagurus) ochotensis BRANDT, loc. cit.

Bernhardus armatus DANA, U. S. Expl. Exped., Crust., I, 442, pl. XXVII, fig. 2.

Eupagurus armatus STIMPSON, Crust. and Echin. Pacific Coast of N. Am., Bost. Jour. Nat. Hist.

The acicle of the outer antennæ in this species is remarkable for its trigonal form and its naked, glossy, iridescent surfaces. The dactyli of the ambulatory feet are long, naked, and as much twisted as in *E. bernhardus*.

We found two adult specimens in Hakodadi Bay, the largest over four inches in length. The original specimen of Dana's *B. armatus* differs from ours in one point only—the greater hand is more elongated and more rounded at its extremity. This, however, is probably nothing more than a mark of immaturity or variety, as other species are often variable in the proportions of the carpus and hand, so that this may be regarded as one of the species common to both sides of the North Pacific Ocean.

338. EUPAGURUS CONSTANS[2] Stimpson

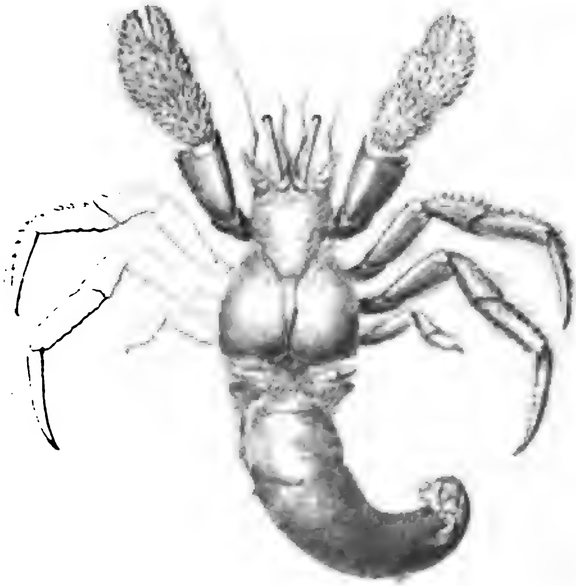
PLATE XXIV, FIG. 3

Eupagurus constans STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 248 [86], 1858.

Body broad and thick; abdomen rather small; sternum somewhat narrower than in *E. bernhardus*. Anterior part of the carapax convex, much indurated, with two arcuated, converging rows of fascicles of setæ, almost obliterated in old specimens. Rostriform point prominent and rather sharp; angle about 60°. Lateral teeth (between eyes and antennæ) acuminated, less prominent than the rostrum. Eyes rather long, but not reaching to the extremity of the

[1] *Pagurus ochotensis* Brandt.

[2] *Pagurus constans* (Stimpson).



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peduncle of the antennæ; peduncles rather stout; cornea scarcely dilated. Acicle long, hairy, and reaching beyond the eyes. On the margin of the second sternal segment, between the bases of the outer maxillipeds, there are two sharp teeth or spines. The right cheliped is very large, reaching much beyond the extremities of the ambulatory feet; ischium-joint with a long, sharp spine at the inner apex; carpus a little longer than broad at its anterior extremity and somewhat longer than the palm of the hand; hand flattened above; fingers shorter than the palm and ornamented above, along their inner margins, with a closely set series of tufts of setæ directed inward. There is a deep notch in the outline of the hand at the outer base of the dactylus. The left cheliped is about one-half as wide as the right, and reaches beyond the base of the right dactylus. In the armature of the surface the chelipeds are much alike; the surface of the meros-joint is unarmed, but sparsely clothed with short series of hairs arising from slight transverse squamiform ridges; the anterior margin of the meros is armed above with comb-like teeth, three in the left, six in the right cheliped; carpus and hand spinous and densely covered with pubescence arising to the tips of the spines. These spines cover the whole upper surface of the carpus; they are strong, sharp, about 1/15 inch in length in adult specimens. On the right hand they form a median and two marginal rows; on the left hand one median row continued on the immovable finger, one row on the outer margin, and a few scattered at the inner base. Between the spines there are small setiferous tubercles.

The ambulatory feet are slender, sparsely hairy in transverse fascicles, and armed with one or two spines on the superior edge of the carpus; dactyli long and slender, longer than the penult joint, not twisted, and sparsely armed with short, stiff hairs; terminal unguiculi very short. Dactylus of the right ambulatory foot of the first pair longer than the carpus of the right cheliped. Feet of the fourth pair very broad, compressed, long-ciliated above; dactylus very short, scarcely overreaching the tip of the process of the penult joint or hand. Color orange, minutely mottled on the body; feet barred above with dark red. Length, about 3.6; length of carapax, 0.8; breadth of front (between bases of outer antennæ), 0.4; length of great cheliped, 2.3 inches.

This species, contrary to the usual practice among hermit crabs, never leaves the habitation (a small shell) it has first selected. In the enlargement of its domicile (carcinœcium) to suit its own growth, it is assisted by a little architect, a hydroid polyp (*Hydractinia sodalis* Stm.), about half an inch in length, which in consider-

able numbers molds its corneous base over the body of the crab, receiving for its reward and sustenance the fragments which float off at the banquet of its voracious companion, as well as free transportation along the sea bottom. The shell thus formed is spiral, with depressed whorls, laxly convoluted and resembling somewhat a *Delphinula*, and often about an inch and a half in length. It is externally muricated with stout processes from one-tenth to one-half an inch in height, one-twentieth in thickness, and more or less branched at the top. Embedded in its apex we find the minute shell, seldom over one-third of an inch in length, which served the hermit for a cell when young.

The same thing was observed by J. E. Gray (see Zoölogist, I, 204) to occur sometimes with the common *Eupagurus bernhardus;* and on our own coast shells inhabited by *Paguri* are often seen leaving the margin at the mouth, continued out to some extent by the addition of the crustaceous or coriaceous polypidom of *Hydractiniæ*. With *Eup. constans,* however, this is a constant characteristic, and to such an extent that the entire shell seems to be composed of the adventitious substance.

Several specimens of this curious species were dredged from a rocky bottom in four fathoms in Hakodadi Bay, Northern Japan.

339. EUPAGURUS PECTINATUS[1] Stimpson

Eupagurus pectinatus STIMPSON, Proc. Acad. Nat. Sci. Phila., X, p. 249 [87], 1858.

On the anterior part of the carapax there are two series of fascicles of hair, as in *E. constans,* enclosing an oval naked space at the middle; also two or three scattering tufts outside of this space posteriorly. On the posterior part there are some tufts on the median and postero-lateral surfaces. Rostriform point small but very acute, and not much projecting. Lateral points or teeth of front acuminated, their tips spiniform, directed a little outward, and projecting nearly as far forward as the rostrum. Eyes long and slender, reaching to the tips of the peduncles of the antennæ and overreaching the hairy acicle; cornea not dilated. Ophthalmic scales with slender acuminate apex. Flagellum of antennæ reaching beyond the tips of the chelipeds; joints minute, setose. Chelipeds considerably shorter than the ambulatory feet; meros with smooth or slightly squamous surface, and with its anterior margin armed above with 2–4 parallel spines like the teeth of a comb; carpus and hand spinous

[1] *Pagurus pectinatus* (Stimpson).

and hairy, the spines long, erect, subequal, and acute, the hair fine, long, and clean, two or three times as long as the spines. Carpus of the right cheliped not longer than broad, but slightly longer than the palm of the hand; its postero-exterior slope smooth; its antero-interior corner spinous; hand slightly convex, regularly covered with spines arranged in eight longitudinal series, those of the outer margin longer, pectiniform, curving upward; fingers depressed, shorter than the palm, and with acuminate corneous tips; spines on outer margin of dactylus long and pectiniform. In the left cheliped the carpus has two longitudinal rows of spines above, separated by a smooth, flattened space; hand convex, spinous, with the median spines longest; fingers nearly devoid of spines. Ambulatory feet stout, overreaching the chelipeds; last three joints broad, long-ciliated above; dactyli compressed, very broad, not contorted, with the sides longitudinally grooved, the upper edge and inner side hairy, and the inferior margin armed with a series of ten black corneous spines; unguicle or tip stout and sharp, black. Dactylus of fourth pair of feet large, reaching much beyond the hand-process, and with a sharp, curved, black unguiculus. Length of the animal, three inches; length of carapax, 0.7; breadth of front, 0.34; length of greater cheliped, 1.42 inch.

It has much general resemblance to *E. constans,* but is easily distinguished by its shorter chelipeds, broader hairy dactyli of the ambulatory feet, and much larger dactylus of the fourth pair of feet.

Found at Hakodadi, Japan.

340. EUPAGURUS TRIGONOCHEIRUS[1] Stimpson

PLATE XXVI, FIG. 2

Eupagurus trigonocheirus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 249 [87], 1858.

This is a large species, allied to *E. pubescens,* but having more strongly marked characters. The characters mentioned in the following description are those in which it is observed to differ from that species.

The body and feet are more or less hirsute, in some individuals densely so, in others very little so, with the chelipeds nearly naked. The chelipeds are granulated; granules on carpus spiniform. Right hand less than twice as long as broad. Right carpus very thick and broad, broader than the hand, and shorter than in *E. pubescens.*

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[1] *Pagurus trigonocheirus* (Stimpson).

Fingers of the right hand stout, with corneous tips. Left hand large, three-fourths as large as the right, broadly trigonal; carina very prominent, denticulated, and situated far to the right of the middle; oblique exterior surface of the hand broadly expanded, concave, and much dilated at the extero-inferior margin. Ambulatory feet of the right side overreaching the right cheliped. Color reddish; feet orange, inclining to clay color, transversely barred with darker. Eggs of the female black. Length about four inches.

This species is common in the Behring Sea. Found at low-water mark on gravel and in ten fathoms, mud bottom, in Seniavine Straits; in twenty fathoms, shelly bottom, in the Arctic Ocean north of Behring Straits; also in Awatska Bay.

341. EUPAGURUS PUBESCENS[1] Brandt

Pagurus pubescens Kröyer, Tidsskrift, II, 251 (partim).
Pagurus (Eupagurus) pubescens Brandt, in Middendorff's Sibirische Reise, Zoöl., p. 111.
Bernhardus pubescens Stimpson, Mar. Inv. Gr. Manan, 59.

Among our boreal and arctic crustacea we find two closely allied species confounded under the name of *Pagurus pubescens*. Kröyer's description in the Tidsskrift applies almost equally well to both. Nor does his figure in the "Voyage en Skandinavie, en Lapponie," etc. (Crust., pl. II, fig. 1), appear to be an accurate representation of either species.

The following is a short special description of the form to which we would hereafter restrict the name *pubescens*, as it is by far the most hairy of the two in thus agreeing with the Tidsskrift description ("pilis flavis dense obsitis"), although not with the figure above quoted.

Body and feet thickly hirsute with long hair. Chelipeds spinulose, spinules rather large and sharply prominent. Right carpus elongated, scarcely broader than the hand. Right hand generally twice as long as broad, but varying much in its proportions; dactylus with corneous tip. Left hand small, not dilated extero-inferiorly; carina median, little prominent, obtuse, and armed with two rows of spinules. Ambulatory feet of the right side in the adult falling short of the extremity of the right hand. Dactyli of the ambulatory feet much curved, and, as in all the species of this group, a little contorted, with the outer side longitudinally grooved. Color usually reddish, with orange abdomen. Carapax pale red. Hands deep red;

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[1] *Pagurus pubescens* Kröyer.

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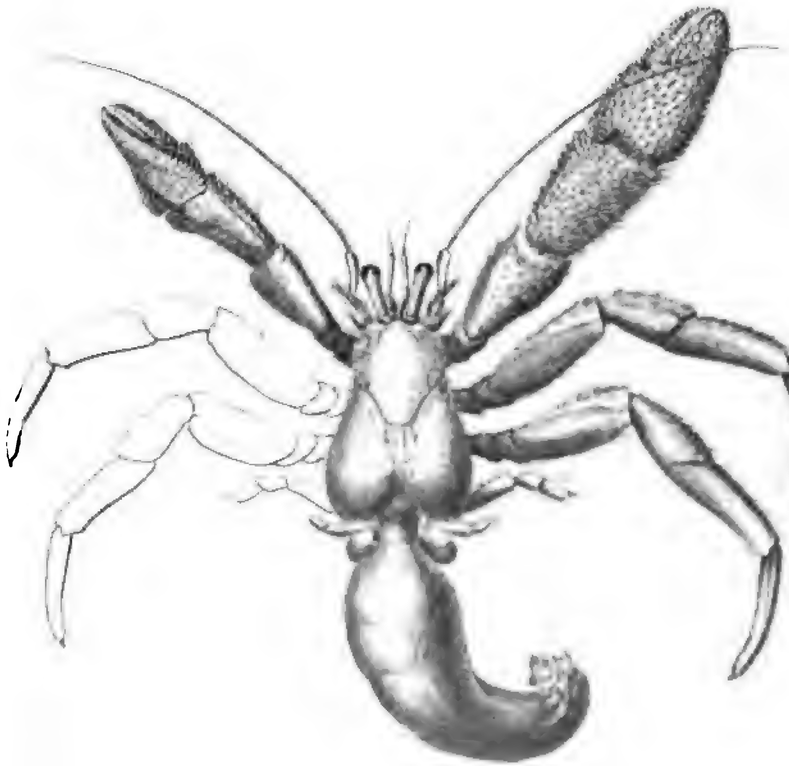

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tips of fingers paler. Ambulatory feet red, with three or four broad, bluish-white transverse bars. Length usually about two or three inches.

The expedition specimen was taken on a muddy bottom in ten fathoms in Awatska Bay, Kamchatka. It is identical with those found on the northeast coast of America.

342. EUPAGURUS PILOSIPES[1] Stimpson

Eupagurus pilosipes STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 249 [87], 1858.

Rostriform point of the front setose. Feet very hairy. Right cheliped spinulose above; carpus with a smooth, shallow longitudinal groove near the inner margin, which is spinous; hand elongated, tapering, sparsely but regularly covered with spiniform tubercles. Left cheliped spinulose above; carpus distinctly grooved; fingers of the hand twice as long as the palm, and broadly gaping. Ambulatory feet longitudinally vittate with red; dactyli a little shorter than the penult joint. Length, one inch.

It is very near *E. hirsutiusculus,* but the ambulatory feet are vittate with red throughout, the fingers of the smaller hand gaping, and the granules of the large cheliped spiniform. It differs from *E. samuelis* in its narrower and more tapering right hand; from *E. pubescens* in the more slender left hand and much shorter dactyli of the ambulatory feet.

Found at Loo Choo.

343. EUPAGURUS HIRSUTIUSCULUS[2] (Dana) Stimpson

Bernhardus hirsutiusculus DANA, U. S. Expl. Exped., Crust., I, 443, pl. XXVII, fig. 3.

Eupagurus hirsutiusculus STIMPSON, Crust. et Echin. Pacific Coast of N. Am., p. 44, Bost. Jour. Nat. Hist.

This species was first described by Dana from specimens taken on the west coast of North America. We add below remarks upon some points which become necessary to distinguish it from allied species herein described.

It is a variable species, usually very hairy, particularly on the ambulatory feet; the chelipeds are often almost naked. It also varies somewhat in the proportions of the carpus and hand in the right

[1] *Pagurus pilosipes* (Stimpson).

[2] *Pagurus hirsutiusculus* (Dana).

cheliped, and in the shape of the hand, which is, however, usually tapering toward the fingers, so that the immovable finger is narrow, with a nearly straight outer margin.

The rostriform point is smaller and less prominent than in Dana's figure, but sharp and distinct. The right cheliped is elongated, does not reach to the extremities of the right ambulatory feet; the granules of its upper surface are distinct and well separated, though not generally very prominent; those of the carpus are sharper or scabriform, and always setose at their bases; the dactylus is ornamented with a row of granules parallel to its outer margin, not represented in Dana's figure. The small cheliped is convex and distinctly grooved longitudinally above, particularly on the carpus, where the groove is defined on either side by a spinous crest, the superior crest being by far the most prominent. Fingers of the smaller hand not gaping, and not over a third or half longer than the palm. Beneath the meros-joint is hairy in both chelipeds. In the small cheliped the sides of this joint are prominent and denticulated with subequal teeth; the surface is granulated. In the larger cheliped this joint is sparsely granulated, one granule or tubercle situated near the apex of the ischium being larger than the rest, but not projecting.

Neither the shape of the anterior part of the carapax nor the granulation of the chelipeds is well represented in the figure taken from the U. S. Exploring Expedition specimen.

It differs from *E. pubescens* in the armature of the hands, which are not spinous, but granulated, and in the shorter dactyli of the ambulatory feet, which are very little longer than the penult joint, and show a longitudinal red stripe on each side.

It is found at Hakodadi, in Japan, in the same abundance as on the opposite shore of the North Pacific.

344. EUPAGURUS SAMUELIS[1] Stimpson

Eupagurus samuelis STIMPSON, Crust. and Echin. Pacific Coast of N. Am., p. 42, Bost. Jour. Nat. Hist.; Notes on N. American Crust., 44, pl. 1, fig. 8.

Closely allied to *E. hirsutiusculus*. The rostriform point is slender, sharp, and distinct in some specimens, but generally obtuse or hidden by a tuft of setæ. The feet are hairy, but much less so than in *hirsutiusculus;* chelipeds usually naked. On the lower surface of the meros-joint in the chelipeds there is a remarkably prominent tubercle, sometimes sharp, but usually blunt, situated near the mid-

[1] *Pagurus samuelis* (Stimpson).

dle in the greater and on the angular prominence to the left in the smaller cheliped. There is sometimes another tubercle by the side of the first in the greater cheliped. The larger hand is broad and somewhat depressed, with the outer margin arcuated, acute, and denticulated; its surface is evenly covered with small, equal, sharply prominent but obtuse granules; fingers generally with corneous tips pretty distinct; dactylus with a series of larger granules above parallel to its outer margin. The smaller cheliped is like that of *E. hirsutiusculus*, but is almost trigonal, with a less distinct longitudinal groove; carpus spinous above; fingers not twice as long as palm, and not gaping. The ambulatory feet are long, those of the right side overreaching the tip of the right hand; dactyli stout, and somewhat shorter than the penult joint. Colors: Carapax red, with a median and two or three lateral bluish stripes. The colors on the feet are arranged by rings or bars, instead of vittæ; in alcoholic specimens these are blue and red; fingers of chelipeds bluish. Length usually one inch; length of anterior region of carapax, 0.25; breadth, 0.21 inch.

Found at Kagosima, Simoda, and Hakodadi, in Japan, as well as on the coast of California.

345. EUPAGURUS ANGUSTUS[1] Stimpson

Eupagurus angustus Stimpson, Proc. Acad. Nat. Sci. Phila., x, p. 250 [88], 1858.

The body in this species is narrow, as in some *Clibanarii*. Feet, with the exception of the right cheliped, moderately pilose, with long, fine hair. Rostriform point short and broad, but acute. Eyes rather long, reaching nearly to the extremities of the peduncles of the antennæ; cornea very little dilated. Ophthalmic scales with acuminate apex. Acicle small and short, falling much short of the extremities of the eyes. Flagellum of the antennæ long, naked, reaching far beyond the tips of the walking feet. Great cheliped much elongated, reaching a little beyond the ambulatory feet, naked except at the base, and everywhere covered above with minute equal spiniform granules; carpus two-thirds as broad as long, and three-fourths as long as the hand, including the fingers; hand convex, a little broader than the carpus, and tapering toward the fingers; fingers small, hardly more than one-half as long as the palm; tips calcareous; dactylus with a granulated longitudinal groove along the back, separating two rows of somewhat larger granules. Beneath

[1] *Pagurus angustus* (Stimpson).

the greater cheliped is granulated; meros-joint with a single prominent tubercle near the middle. The small cheliped extends to or a little beyond the extremity of the greater carpus; it is ridged along the middle, spinulose and hairy; spinules longest on the carpus; hand rather swollen exteriorly, with a depression on the right side of the palm above; fingers long and somewhat gaping. Ambulatory feet rather compressed; superior edge of carpal joint armed with four or five spinules; dactyli not contorted, slightly longer than the penult joint; unguicle or tip long and slender.

The colors in the alcoholic specimen are light yellow and red, arranged in broad, transverse bands or annulations on the feet; middle of the dactyli whitish, base and tips red. Length of the animal, 1.6; length of carapax, 0.35; breadth of front, 0.16; length of right cheliped, 0.96 inch.

Allied to *E. granosimanus* of the opposite shores of the Pacific, from which it differs in its narrower carapax, more acute and prominent rostriform point, and in the sharper granules of the right cheliped.

Found at the island of Kikaisima, in a small harbor on its southern coast.

346. EUPAGURUS MIDDENDORFFII [1] Brandt

Pagurus (*Eupagurus*) *middendorffii* Brandt, in Middendorff's Sibirische Reise, Zoölogie, p. 108, pl. v, figs. 1-16.

This species is easily recognized among other North Pacific *Eupaguri* by the smooth and even surface of its chelipeds, and its very slender ambulatory feet. There are no tubercles on the lower surface of the meros-joint of the great cheliped.

Our specimens were found in Hakodadi Bay, Japan.

347. EUPAGURUS JAPONICUS [2] Stimpson

Plate XXV, Fig. 2

Eupagurus japonicus Stimpson, Proc. Acad. Nat. Sci. Phila., x, p. 250 [88], 1858.

The following is a description of a male: Anterior region of the carapax well indurated, convex, and glabrous. Rostriform point of the front very prominent and acute; lateral points also prominent and minutely apiculated. The median region is broad, and the chan-

[1] *Pagurus middendorffii* Brandt.

[2] *Pagurus japonicus* (Stimpson).

nels bounding it laterally are, as usual, occupied with fascicles of hair, largest anteriorly. Eyes more than half as long as the front is wide; cornea a little dilated. Apical portion of the ophthalmic scale oblong, constricted at the base, but not acuminated at the extremity, and marked above by a median longitudinal impressed line occupied by short setæ. Acicle of the antennæ long, overreaching the eyes, and thickly clothed with tufts of hairs on its upper or inner edge; flagellum short, setose at the joints. Exognath of the outer maxillipeds broad.

The chelipeds, both right and left, are large and much longer than the contiguous ambulatory feet. Right cheliped densely clothed above with soft and rather short hair; meros smooth above and unarmed at the superior margin, but beneath very much dilated and hairy, with the right margin pectinated, the left most expanded and ciliated with long hairs; upper surface of carpus and hand covered with small scabriform granules, from the bases of which the hairs arise; carpus as long as the palm of the hand, armed with several small purple spines at the inner margin and near the antero-interior corner, and marked along the middle with a smooth groove; hand large, a little more than twice as long as broad; palm with a row of minute spines down the middle; exterior margin of immovable finger denticulated with spiniform teeth; dorsal carina of dactylus armed with a series of twelve bluish teeth. The left cheliped is also scabrous and hairy; meros and carpus almost or quite equal to those of the right cheliped in length, but much narrower and more compressed; lower outer margins of meros and carpus and upper margin of carpus spinous; hand somewhat tetragonal, carinated at the middle above, and at the outer margin; upper carina spinous. Ambulatory feet short and stout, thickly hairy above, but not spinulose; dactyli broad, not contorted, and shorter than the penult joint; ungues very large and strong. Color inclining to orange or minutely mottled with red and yellow; ambulatory feet broadly annulated with deeper red. Length of the animal, about 3.2; length of carapax, 0.83; breadth of front, 0.38; length of greater cheliped, 2.08 inches.

It somewhat resembles the *Pagurus lanuginosus* of De Haan, in which species, however, the ambulatory feet overreach the chelipeds and "manu pedum secundorum tarsis parum breviore." In our species the hand, even the left hand, is longer than the longest "tarsus."

Our specimens were found at Simoda.

348. EUPAGURUS SINUATUS[1] Stimpson

PLATE XXVI, FIG. 1

Eupagurus sinuatus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 250 [88], 1858.

Upon the anterior region of the carapax there are the usual two series of setose pits extending on either side, from the base of the eye to the middle of the lateral suture. Rostriform tooth acute, prominent; lateral teeth of front acuminated. Eyes stout, shorter than the acicles; cornea a little dilated. Apex of ophthalmic scales elongated and slender. The greater cheliped reaches to the tips of the walking feet; surface granulated and covered with a short pubescence; inner margin with a deep sinus at the juncture of the carpus and the hand and another at the juncture of the dactylus with the hand; carpus subtriangular, sparsely spinous above, with a smooth strip in the middle and a spinose inner margin; hand broad in the female, with a median, and marginal rows of subspiniform granules larger than the rest; dactylus above armed with a median series of sharp tubercles. Small cheliped subtrigonal, hirsute, and granulated; carpus with a spinous edge and a longitudinal smooth channel above; hand not spinous, but with a blunt carina running from the base to the immovable finger. In both chelipeds the meros is deeply excavated beneath, with the margins long-ciliated; the right margin spinose. Ambulatory feet hairy, but not spinose above; tarsi rather broad, not twisted, and armed with corneous spinules. Color of alcoholic specimens reddish. General length of a male specimen, 2.2; length of carapax, 0.6; breadth of front, measured as usual, between the outer bases of the antennæ, 0.3; length of greater cheliped, 1.28 inches.

Found in Port Jackson, Australia.

349. EUPAGURUS TRICARINATUS[2] Stimpson

Eupagurus tricarinatus STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 251 [89], 1858.

Eyes rather remote from each other, and pretty large and stout, in length about equaling the peduncle of the antennæ, but overreaching the acicle; cornea considerably dilated; peduncle constricted at base. There is no distinct median or rostriform point to the carapax, but the bracteole or interocular plate of the ophthalmic ring is consider-

[1] *Pagurus sinuatus* (Stimpson).

[2] *Pagurus tricarinatus* (Stimpson).

ably developed. Feet naked or nearly so. Chelipeds shorter than the ambulatory feet; the right one but little larger than the left; hand in both with three sharp, denticulated longitudinal keels or crests, two marginal, and one median one continued on the immovable finger; carpus slightly pilose, flattened or obsoletely grooved above, with two slight crenated keels. Ambulatory feet very slender, naked; dactyli not contorted, and much longer than the penult joint. Colors: Body dark brownish in front, paler posteriorly; feet transversely banded with reddish and olive; chelipeds white. General length of the animal, half an inch; length of the carapax, 0.11; breadth of the front, 0.07; length of the right cheliped, 0.17 inch.

Dredged in five fathoms, black sand, in Kagosima Bay, Japan.

350. EUPAGURUS ACANTHOLEPIS[1] Stimpson

Eupagurus acantholepis STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 251 [89], 1858.

Of this species we have only a small female specimen, perhaps young. The rostriform tooth is obsolete. The ophthalmic ring is shielded above by a bifurcated bracteole. The eyes are slender, and overreach the peduncles of the antennæ, equaling in length the breadth of the front, and curving outward; cornea not dilated; ophthalmic scales small, bidentate or bifurcated; teeth or forks spiniform. Flagellum of antennæ shorter than the feet. Acicle very small. Feet slender, sparsely hirsute with long hairs. Chelipeds slender, but much shorter than the ambulatory feet, and spinulose above; the right one largest; carpus somewhat grooved above; hands a little depressed, and armed with a median and two marginal rows of spines; spines of the left cheliped longest. Dactyli of the ambulatory feet not contorted, but compressed, almost falciform; unguicles slender. Fourth pair of feet not didactyle; penult joint expanded. On the right side of the abdomen near its base there is a conical process, the skin of which at its apex is somewhat indurated or corneous. Length of the animal, about one inch; length of carapax, 0.21; breadth of front, 0.12; length of eye, 0.12; length of right cheliped, 0.35; of the right ambulatory foot, 0.53 inch.

This species, as will be seen from the description, presents some peculiarities which may require its subsequent removal from the genus *Eupagurus*, although it has most of the more essential characters of that genus—the remoteness of the external maxillipeds, etc. It is desirable that the male should be examined.

Dredged in eight fathoms, mud, in Port Jackson, Australia.

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[1] *Pagurus acantholepis* (Stimpson).

Genus GALATHEA Fabricius

In the male of this genus the genital organs of the fifth coxæ are not exserted. The segments of the abdomen are all provided with appendages; those of the first two pairs are copulative, and those of the next four pairs are of small size, simple and flattened.

This genus is found in all seas of the old world. It is remarkable that no species is found in the American waters except those of the frigid zones, although it is represented on the west coast by the genus *Pleuronchodes*. The following is a list of species known besides those herein described:

Galathea strigosa Fabr.
squamifera Leach.
nexa Embleton.
andrewsi Kinahan.
tridentata Esmark.
intermedia Liljeb.
serricornis Lovén.

Galathea latirostris Dana.
spinosirostris Dana.
vitiensis Dana.
longirostris Dana.
elegans White.
integrirostris Dana.

351. GALATHEA AUSTRALIENSIS Stimpson

Galathea australiensis Stimpson, Proc. Acad. Nat. Sci. Phila., x, p. 251 [89], 1858.

Carapax rather short and broad; broad posteriorly; surface strigose and pubescent; pubescence rather long; gastric region moderately well defined and two-spined in front; lateral or marginal spines sharp, eight in number on each side, including two at the insertion of the antenna, one above and one below. Rostrum broad, triangular, with four long, deeply cut spiniform teeth on each side; surface thickly pubescent. Chelipeds moderately robust, scabrous and setose above, and with a few spines on the margin; fingers depressed, not gaping, and together nearly as broad as the palm; their inner margins armed with one or two slight teeth. Color reddish, with some bluish on the carapax; fingers of the hands tipped with dark purplish-brown.

The above description was taken from a female specimen, the dimensions of which are: Length of the carapax (rostrum included), 0.29; breadth, 0.215; length of the rostrum, 0.09; of the chelipeds, 0.56 inch.

It was found among sponges dredged from a muddy bottom in six fathoms in Port Jackson, Australia.

352. GALATHEA LABIDOLEPTA Stimpson

Galathea labidolepta STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 251 [89], 1858.

Carapax rather short, narrowing anteriorly; surface strigose and much pubescent; gastric region not distinctly circumscribed, and armed with two little spines anteriorly; lateral margin armed with eight minute spines, including two at insertion of antenna. Rostrum long, triangular, acute, and armed on each side with four small, very slender teeth, including that situated above the eye. No other tooth on the supraorbital margin. Outer angle of orbit acute. Chelipeds rather stout; upper surface uniformly roughened with short spines and setæ; margins armed with a few spines, of which there are two short and one long one near the inner apex of the meros, and one long one at that of the carpus; hand with a thick palm, but very slender fingers, which together are much narrower than the palm, straight, and not toothed. Ambulatory feet spinulose and very sparsely hairy; meros-joint sufficiently broad, and provided on superior margin with about ten weak spines; lower margin of dactylus armed with four small teeth, each bearing one movable spinule. Colors: Carapax dark red, margined with white; abdomen variegated with reddish and yellowish, with a white median spot on each of the first two segments; feet punctate with blue. The dimensions of a male specimen are: Length of the carapax, 0.32; breadth, 0.21; length of rostrum, 0.11; of chelipeds, 0.58 inch. Females are generally larger, the carapax in one being 0.4 inch in length.

Dredged from a sandy bottom in twelve fathoms in Simons Bay, Cape of Good Hope.

353. GALATHEA ORIENTALIS Stimpson

Galathea orientalis STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 252 [90], 1858.

The following description is that of a male. Carapax rather long and narrow, becoming narrower anteriorly; surface, as usual, strigose; pubescence on the strigæ very short; gastric region not distinctly defined and two-spined in front, spines minute; lateral margin armed with six teeth or spines, including that above the insertion of the antenna, but not the small inferior one. Rostrum large, subtriangular, and rather broad; surface naked; sides somewhat convex and each armed with three acute equal teeth and one much smaller one at the base. Eyes large. The tooth forming the external angle of the orbit is minute, sharp, and placed rather within than an-

teriorly to the prominent first lateral tooth. Chelipeds long, spinulose, and sparsely provided with long hairs; marginal spines longest; carpus with one strong spine on the inner side and a smaller one behind it; hand rather depressed, uniformly roughened above with asperities or short, broad spinules; fingers scarcely gaping; two low teeth on the inner margin of the dactylus and one on that of the immovable finger corresponding to the interspace between them. Meros-joint of the ambulatory feet rather narrow, with its superior margin armed with equal, closely arranged spinules; dactylus with a short supplementary unguiform tooth on the inner margin above the true unguiculus. Dimensions: Length of carapax, 0.26; breadth, 0.19; length of rostrum, 0.09; of chelipeds, 0.6 inch.

Females have more slender chelipeds, armed with longer spines, and with the fingers scarcely toothed within.

The species is of a bright red color, with a median white stripe on the back. Feet pale orange.

It differs from *G. vitiensis* in its larger rostrum, the non-circumscribed gastric area, and the sharper external orbital angle; from *G. latirostris* in its rostrum, which is longer, not subovate, and more acutely toothed; from *G. spinosirostris* in its longer chelipeds, with fewer spines on the inner side of the carpus.

Dredged from a shelly bottom in twenty-five fathoms in Ly-i-moon Passage, near Hongkong, China.

Specimens probably of this species were obtained in the China Sea, also at Ousima and in Kagosima Bay, which differ somewhat from the above, the males having a somewhat longer and more tapering carapax, with the gastric region better circumscribed; the chelipeds longer and often with gaping fingers, bearing a sharply prominent tooth on the dactylus and none on the immovable finger. This form appears to be connected with the type by intermediate gradations, but if distinct might be named *G. longimana*.

354. GALATHEA ACANTHOMERA Stimpson

Galathea acanthomera STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 252 [90], 1858.

This species resembles *G. orientalis* in the shape and armature of the carapax and rostrum, except that the basal teeth of the rostrum are larger. The chelipeds in our only specimen are wanting. The ambulatory feet resemble those of *G. spinosirostris*. They are stout and fringed above with plumose hairs; the meros-joint is broad, with eleven stout spines on the superior edge, with the outer surface deeply marked with pubescent strigæ, and with a spine at the inferior extremity; the carpus is four-spined above, and the dactylus

is less than half as long as the penult joint, and armed below with a minute supplementary unguiculus. The upper surface of the abdomen is sparsely clothed with long hairs. Color grayish. Length of carapax, 0.22; breadth, 0.18; length of rostrum, 0.07 inch.

It differs from *G. spinosirostris* in its longer rostrum and in the plumose character of the setæ on the ambulatory feet.

Found among coral at the depth of one fathom in Port Lloyd, Bonin Islands.

355. GALATHEA PUBESCENS Stimpson

Galathea pubescens STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 252 [90], 1858.

Carapax regularly or evenly convex, not much narrowed before; surface deeply strigose and conspicuously pubescent, the hairs or ciliæ of each ridge being nearly long enough to reach the next ridge. Gastric region not well defined, and armed near the middle anteriorly with three small spines, the median one situated a little behind the other two. Lateral margins armed as in *G. orientalis*. Rostrum large, acutely triangular, densely pubescent above, and 4-toothed on each margin; teeth very sharp, and raking forward. There is sometimes a supplementary tooth between the basal tooth and the second. Chelipeds linear, very slender, sparsely setose and spinulose, but with spines smaller and less numerous than in *G. orientalis*. Sometimes there is, however, a strong spine on the carpus. Fingers of the hand flattened, parallel, not at all gaping, and not as long as the palm. Ambulatory feet of moderate length; superior edge of meros-joint armed with seven or eight very slender subdistant spinules; dactylus about half as long as the penult joint. Abdomen pubescent. Color reddish, sometimes with darker mottlings, and a median dorsal white stripe. In one specimen the length of the carapax was 0.22; breadth, 0.16 inch. In another, a female, length of carapax, 0.22; breadth, 0.13; length of rostrum, 0.08; length of chelipeds, 0.4 inch.

It was dredged from a sandy bottom in thirty-three fathoms on the east coast of Ousima; also in twenty-five fathoms, coarse sand and shells, off the headland of Hakodadi, Island of Jesso, Japan.

356. GALATHEA SUBSQUAMATA Stimpson

Galathea subsquamata STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 252 [90], 1858.

Carapax depressed, scarcely narrowed anteriorly. The transverse strigæ are few in number (only three on the cardiac region), the

secondary ones being obsolete; but they are very deeply cut, especially at the middle of the carapax. On the gastric region and at the sides these strigæ are undulated, and sometimes partially interrupted, so as to resemble broad scales. Their edges are scarcely pubescent, and there are only a few scattered setæ on the surface. The gastric and hepatic regions are not very distinctly circumscribed. On the front and sides of the gastric region there are eight or ten small spinules scattered. Lateral margin seven-toothed, excluding the angle of the orbit, which is situated far inward, as in *G. orientalis*. Rostrum exactly triangular in shape, of the usual breadth, and armed with four very sharp and deeply cut teeth on each side. Spines on the base of the antennulæ very long, reaching almost to the tip of the rostrum. Chelipeds of moderate size, armed with small subequal spines regularly distributed; carpus and meros with two or three longer spines within; hand more slender than carpus; fingers parallel, depressed, not gaping, and not toothed. In the ambulatory feet the meros is slender, and ten-spined above; dactylus with a short, stout tooth on the inner or lower margin. Length of carapax in a male, 0.26; breadth, 0.16; length of rostrum, 0.1; of chelipeds, 0.56 inch.

Found at Ousima.

357. GALATHEA GRANDIROSTRIS Stimpson

Galathea grandirostris Stimpson, Proc. Acad. Nat. Sci. Phila., x, p. 252 [90], 1858.

Carapax evenly convex; strigose; strigæ about twelve in number between the base of the rostrum and the posterior margin, and ciliated with short hairs, equaling in length one-third the distance between the ridges. Some of the strigæ are interrupted, and that which crosses the posterior part of the gastric region is undulated. Gastric region not circumscribed. Lateral margin nine-toothed. Rostrum greatly elongated; surface roughened and pubescent; margins each serrated with about six small distant teeth almost obsolete. Chelipeds stout, roughened with transverse scabrosities and short setose; two or three spines at the inner apex of the meros and of the carpus; no spines on the hand; fingers moderately pilose and not gaping. The surface of the ambulatory feet is ornamented with transverse ciliated striæ, about six in number on the meros-joint. Color purple-brown, very dark; carapax and abdomen above with two longitudinal yellowish-white vittæ; chelipeds with one median stripe; ambulatory feet transversely barred. Length of carapax in a male (rostrum included), 0.342; breadth, 0.19; length of rostrum.

0.16; breadth of rostrum at base, 0.06; length of chelipeds, 0.53 inch.

With *G. longirostris* Dana and *G. elegans* White it forms a group which will perhaps be found to have a generic value, and be separated from *Galathea* proper. From these two species ours differs in its larger rostrum and in other characters.

It was dredged from a black sand bottom at five fathoms depth in Kagosima Bay, Japan.

Genus MUNIDA Leach

Differs from *Galathea* in the character of its front, which is armed with three spines, the median longest. The species of *Munida* are all very closely allied to each other. They are found in both temperate zones and in both oceans. Only three species are known, *M. bamffia* White, *M. subrugosa* Dana, and the following.

358. MUNIDA JAPONICA Stimpson

Munida japonica STIMPSON, Proc. Acad. Nat. Sci. Phila., x, p. 252 [90], 1858.

The carapax is oblong. The lateral margin is armed near the middle with five spinules, and the spines above and behind the base of the antenna are no larger than these lateral spinules. There is a pencil of brilliant setæ on the margin beneath the sinus of the transverse suture, and a few such pencils on the sides of the abdomen. Frontal spines needle-shaped, the lateral ones nearly half as long as the middle one. There is a series of thirteen spinules extending across the front part of the gastric region, of which two, one on each side of the middle, are larger than the others. On each side of the gastric region there are three spines on the surface, about half way from the lateral margin to the median line. Chelipeds very long, straight, subcylindrical, scabrous, with a few scattered spinules; fingers long, very slender, and straight, those of the left hand gaping at the base. Antennæ a little longer than the chelipeds. Color a rather dark red, mottled with light red and white. The feet show a tendency to annulation. This description is drawn up from a male specimen, the dimensions of which are: Length of carapax, 0.48; breadth, 0.28; length of median frontal spine, or rostrum, 0.18; length of chelipeds, 1.3 inches.

Dredged from a shelly bottom in twenty fathoms in Kagosima Bay, Japan.

EXPLANATION OF PLATES.

PLATE I.

FIG. 1. *Doclea gracilipcs,* natural size.
2. *Micippa spinosa,* ×, 2/3.
3. *Micropisa ovata,* ♂, × 2.
3*a*. Ventral view of anterior half, × 5.
4. *Doclea canalifera,* ♂, × 4/5.

PLATE II.

FIG. 1. *Hyas latifrons,* ♂, × 2/3.
1*a*. Carapace of young specimen, natural size.

PLATE III.

FIG. 1. *Tiarinia cornigera,* ♂, natural size.
2. *Tiarinia depressa,* ♀, natural size.
3. *Tiarinia spinigera,* ♀, natural size.
4. *Scyra compressipes,* ♀, natural size.
5. *Achæopsis spinulosus,* ♀, natural size.
5*a*. Carapace of ♀, × 2.
6. *Menæthius dentatus,* natural size.
7. *Achæus lacertosus,* ♂, natural size.
8. *Stenorynchus falcifer,* ♀, natural size.

PLATE IV.

FIG. 1. *Mithrax suborbicularis,* natural size.
2. *Eurynome longimana,* ♂, natural size.
3. *Lambrus rugosus,* ♂, natural size.
4. *Lambrus tuberculosus,* ♂, natural size.
5. *Cancer productus,* ♀, × 2/3.
5*a*. Buccal and antennal region.
6. *Cryptopodia contracta,* ♂, natural size.
6*a*. Ventral view.

PLATE V.

FIG. 1. *Liomera subacuta,* ♀, natural size.
2. *Etisus convexus,* ♀, natural size.
3. *Xanthodes elegans,* ♀, natural size.
4. *Lachnopodus rodgersii,* ♀, natural size.
5. *Actæa subglobosa,* ♂, natural size.
6. *Actæa pilosa,* ♂, × 2.
7. *Actæa pura,* ♀, natural size.

PLATE VI.

FIG. 1. *Polycremnus verrucifer*, ♂, natural size.
2. *Euxanthus melissa*, ♂, natural size. *a.* Right chela. *b.* Abdomen.
3. *Chlorodius exaratus* var. *granulosus*, ♂, natural size.
4. *Chlorodius exaratus* var. *rugosus*, ♂, natural size.
5. *Chlorodius dentifrons*, ♂, × 2.
6. *Chlorodius exaratus* var. *pictus*, ♂, natural size.
7. *Chlorodius exaratus* var. *acutidens*, ♂, natural size.
8. *Chlorodius exaratus* var. *cupulifer*, chelæ, natural size.
9. *Chlorodius exaratus* var. *latus*, ♂, natural size.

PLATE VII.

FIG. 1. *Pilodius nigrocrinitus*, ♀, × 2. *a.* Dorsal view. *b.* Right chela.
2. *Pilodius granulatus*, ♂, × 2.
3. *Pseudozius microphthalmus*, ♀, natural size.
4. *Ozius frontalis*, ♂, natural size.
5. *Sphærozius nitidus*, ♀, × 2.
5*a*. Front view.
6. *Ozius rugulosus*, ♀, × 4/5.
7. *Heteropanope australiensis*, ♂, natural size.
7*a*. Outline of carapace, × 2.

PLATE VIII.

FIG. 1. *Heteropanope glabra*, ♂, × 2.
2. *Heteropanope eucratoides*, ♂, × 2.
2*a*. Chelæ, × 2.
3. *Pilumnus rufopunctatus*, ♂, natural size.
4. *Pilumnus fissifrons*, ♂, × 2.
5. *Pilumnus verrucosipes*, × 2
6. *Pilumnus forficigerus*, ♀, × 2.
6*a*. Chelæ, × 2.
7. *Pilumnus lapillimanus*, ♂, natural size.
7*a*. Chelæ, natural size.

PLATE IX.

FIG. 1. *Pilumnus hirsutus*, ♂, × 2.
2. *Pilumnus marginatus*, ♂, × 2,
3. *Pilumnus dorsipes*, natural size.
3*a*. ♂, natural size, showing feet in dorsal position.
4. *Tetralia lævissima*, ♂, × 2.
4*a*. Left chela, × 2.
5. *Trapezia reticulata*, ♂, × 2.
6. *Portunus strigilis*, × 2.
7. *Charybdis variegata*, carapace of ♂, × 2.

PLATE X.

FIG. 1. *Amphitrite media*, ♀, natural size.
2. *Amphitrite gracillima*, ♂, × 2.
3. *Amphitrite gracilimanus*, ♂, natural size. *a*. Dorsal view. *b*. Right chela and carpus. *c*. Abdomen.
4. *Kraussia nitida*, ♂, × 2.
5. *Thalamita picta*, ♂, natural size.
6. *Thalamita crenata*, ♂, × 2/3.
6*a*. Right chela.

PLATE XI.

FIG. 1. *Thalamita danæ*, ♀, × 4/5.
1*a*. Right chela.
2. *Thalamita sima*, ♂, × 2/3.
3. *Pilumnoplax sculpta*, ♀, × 2.
4. *Acmæopleura parvula*, ♂, × 2.

PLATE XII.

FIG. 1. *Charybdis anisodon*, ♂, × 2/3.
2. *Ocypode ceratophthalma*, eyes of three specimens, largest and smallest ♂, medium ♀.
3. *Cheirogonus acutidens*, slightly enlarged.

PLATE XIII.

FIG. 1. *Macrophthalmus dentatus*, ♂, × 2. *a*. Dorsal view. *b*. Right chela. *c*. Left chela.
2. *Macrophthalmus convexus*, ♂, × 2. *a*. Dorsal view. *b*. Left chela.
3. *Macrophthalmus serratus*, ♂, natural size. *a*. Carapace. *b*. Left hand. *c*. Ambulatory leg. *d*. Extremity of leg.
4. *Myctiris brevidactylus*, ♂, natural size.
5. *Myctiris platycheles*, ♂, natural size.
6. *Sesarma vestita*, upper view of left chela, × 3.

PLATE XIV.

FIG. 1. *Asthenognathus inæquipes*, ♀, × 2.
2. *Gelasimus splendidus*, ♂, natural size. *a*. Dorsal view. *b*. Inner side of large chela. *c*. Outer side of large chela.
3. *Gelasimus acutus*, ♂, natural size. *a*. Dorsal view. *b*. Outer side of large chela. *c*. Inner side of large chela.
4. *Gelasimus dubius*, ♂, natural size. *a*. Dorsal view. *b*. Outer side of large chela.
5. *Cryptocnemus pentagonus*, × 2. *a*. Rear view. *b*. Side view.
6. *Cryptocnemus pentagonus*, ♂, × 2. *a*. Dorsal view. *b*. Ambulatory leg.
7. *Carcinaspis marginatus*, ♀, × 2.
8. *Hapalocarcinus marsupialis*, ♀, × 2.

PLATE XV.

FIG. 1. *Gelasimus pulchellus*, ♂. *a*. Dorsal view, × 2. *b*. Outer side of large chela, natural size. *c*. Inner side of large chela, natural size.
2. *Ocypode cordimana*, ♂, natural size. *a*. Dorsal view. *b*. Abdomen of male. *c*. Abdomen of female. *d*. Buccal area.
3. *Ocypode convexa*, natural size. *a*. Dorsal view. *b*. Right chela. *c*. Left chela.

PLATE XVI.

FIG. 1. *Nautilograpsus angustatus*, × 2.
2. *Metopograpsus quadridentatus*, inner face of right arm of ♂, natural size.
3. *Geograpsus rubidus*, ♂, × 4/5.
3*a*. Lower view of left chela of ♂, natural size.
4. *Grapsus subquadratus*, ♂, × 4/5.

PLATE XVII.

FIG. 1. *Sesarma rupicola*, natural size.
1*a*. Upper view of right chela and wrist of ♀, natural size.
1*b*. Upper view of palm and base of dactylus of ♀, × 2.
2. *Geothelphusa dehaani*, ♂, × 1/2.
3. *Platygrapsus convexiusculus*, ♀, natural size.
4. *Camptandrium sexdentatum*, ♀, × 2.
5. *Ptychognathus glaber*, ♂, natural size.
5*a*. Buccal area.

PLATE XVIII.

FIG. 1. *Leucosia parvimana*, ♂, natural size. *a*. Dorsal view. *b*. Abdomen of male.
2. *Leucosia maculata*, ♂, natural size. *a*. Dorsal view. *b*. Abdomen.
3. *Leucosia vittata*, ♂, natural size.
3*a*. Carapace of young ♂, natural size.
4. *Philyra unidentata*, ♀, natural size.
5. *Philyra tuberculosa*, ♀, natural size.
6. *Phlyxia quadridentata*, ♂, × 2.
7. *Ebalia madeirensis*, ♀, × 2.
8. *Iphiculus spongiosus*, natural size. *a*. Carapace. *b*. Left chela. *c*. Side view.
9. *Arcania globata*, ♀, natural size.

PLATE XIX.

FIG. 1. *Remipes testudinarius*, natural size.
2. *Diogenes brevirostris*, ♂, × 2.
3. *Tymolus japonicus*, ♂, × 2.
3*a*. Carapace of ♀, × 2.
4. *Ethusa sexdentata*, ♂, × 2.
5. *Polyonyx sinensis*, ♂, × 2.

FIG. 6. *Oreophorus rugosus,* ♀, natural size.
6a. Abdomen of ♀.
7. *Cycloës cristata,* ♂, × 2.
8. *Onychomorpha lamelligera,* ♂, × 2.
8a. Ambulatory leg.

PLATE XX.

FIG. 1. *Dromidia spongiosa,* ♀, natural size.
2. *Cryptodromia coronata,* ♂, × 2.
3. *Cryptodromia lateralis,* ♂, × 2.

PLATE XXI.

FIG. 1. *Mastigopus gracilis,* × 2.
2. *Hippa analoga,* ♀, natural size. *a.* Dorsal view. *b.* Side view of carapace.
3. *Pseudodromia latens,* ♂, natural size.
4. *Petalomera granulata,* carapace, × 2.
5. *Conchœcetes artificiosus,* ♂, natural size.
6. *Cryptodromia tuberculata,* ♂, natural size.
7. *Dromia rumphii,* abdomen of ♂, hairs removed.

PLATE XXII.

FIG. 1. *Porcellana pulchra,* ♀, × 3.
2. *Petrolisthes speciosus,* ♂, natural size.
3. *Petrolisthes pubescens,* ♂, × 2.
4. *Petrolisthes hastatus,* ♂, natural size.
5. *Raphidopus ciliatus,* ♀, × 2.
6. *Porcellanella picta,* ♂, natural size.

PLATE XXIII.

FIG. 1. *Porcellana streptocheles,* ♂, × 2.
2. *Porcellana serratifrons,* ♂, × 2.
3. *Porcellana dispar,* ♂, × 2.
4. *Porcellana latifrons,* ♂, × 2.
5. *Pachycheles pectinicarpus,* × 2.
6. *Pachycheles stevensii,* ♀, natural size.

PLATE XXIV.

FIG. 1. *Diogenes edwardsii,* ♂, natural size.
2. *Eupagurus megalops,* natural size.
3. *Eupagurus constans,* ♂, natural size.

PLATE XXV.

FIG. 1. *Paguristes digitalis,* ♂, natural size, Hakodadi.
2. *Eupagurus japonicus,* ♂, natural size.

PLATE XXVI.

FIG. 1. *Eupagurus sinuatus,* ♀, natural size, Port Jackson.
2. *Eupagurus trigonocheirus,* natural size.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

PART OF VOL. XLIX

SAMUEL PIERPONT LANGLEY

Secretary of the Smithsonian Institution, 1887-1906

MEMORIAL MEETING

December 3, 1906

ADDRESSES BY

DOCTOR WHITE, PROFESSOR PICKERING, AND MR. CHANUTE

(No. 1720)

CITY OF WASHINGTON
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WASHINGTON, D. C.,
PRESS OF JUDD & DETWEILER, INC.
1907

In Memory

OF

SAMUEL PIERPONT LANGLEY

Born in Roxbury, Mass., August 22, 1834
Died in Aiken, S. C., February 27, 1906

SMITHSONIAN INSTITUTION
CITY OF WASHINGTON

The Board of Regents of the Smithsonian Institution
invite you to attend a meeting
to Commemorate the Life and Services of

SAMUEL PIERPONT LANGLEY

Secretary of the Smithsonian Institution from 1887 to 1906

in the Lecture Room of the United States National Museum
Monday Evening, December Third
Nineteen Hundred and Six, at 8.15 o'clock

The following Addresses will be Delivered:

Introductory Remarks
by the Chancellor of the Smithsonian Institution
The Honorable Melville W. Fuller
Chief Justice of the United States

Memorial on Behalf of the Board of Regents
by the Honorable Andrew D. White, LL. D.

Mr. Langley's Contributions to Astronomy and Astrophysics
By Professor E. C. Pickering
Director of the Harvard College Observatory

Mr. Langley's Contributions to Aerodynamics
By Octave Chanute, Esquire, of Chicago

SAMUEL PIERPONT LANGLEY.

MEMORIAL MEETING, DECEMBER 3, 1906.

At a meeting of the Board of Regents of the Smithsonian Institution, March 6, 1906, the Chancellor announced the death, on February 27, 1906, of Samuel Pierpont Langley, Secretary of the Institution from 1887 to 1906, and it was

Resolved, That the Executive Committee be requested to arrange for a memorial meeting to be held in Washington.

A meeting was accordingly arranged for the evening of December 3, 1906, and invitations were sent to a large number of officials and friends of the late Secretary.

The meeting was called to order by the Chancellor of the Institution, who presided.

INTRODUCTORY REMARKS.

THE CHIEF JUSTICE: The fame of men who have achieved eminence in science and in kindred activities, as well as in administration, is a common heritage, and those who are not experts in the particular art are as much entitled to bear witness to their appreciation of that fame as the experts themselves or the rare individuals who may be said to have taken knowledge for their province. We proceed tonight to pay due tribute to our dear friend, Doctor Langley, and to his distinguished scientific labors in general and especially as Secretary of this Institution.

It gives me great pleasure to introduce to you Doctor Andrew D. White, whose illustrious career as diplomatist, publicist, university president, and author is too widely known to justify more than a mere allusion.

SAMUEL PIERPONT LANGLEY.

BY ANDREW DICKSON WHITE.

The Smithsonian Institution, devoted as it is to "the increase and diffusion of knowledge among men," has given inspiration and force

to a great multitude of quiet workers, as well in other countries as in our own, but it has been chiefly represented before the world thus far by its three successive secretaries.

First, by Joseph Henry, a physicist, who, in the simple love of truth, utterly regardless of wealth, honors, or power, devoted himself to the discovery of principles which, since his time, have given a bloom and fruitage of invention enriching his country and the world.

Next, by Spencer Fullerton Baird, a naturalist, equally regardless of riches or applause, who studied devotedly various forms and phases of life on our planet, who also inspired and strengthened thousands of lesser thinkers and workers, and who opened anew a vast field for profitable human toil.

And latest by him whom we today commemorate, Samuel Pierpont Langley, a physicist and astronomer, who wrought mainly in fields far more remote from immediate human interests than those cultivated by his predecessors, yet who proved himself in spirit, thought, labor, and achievement fully worthy to be ranked with them.

I am asked to speak of him as a *man;* of his relations to his fellow-men, and of his work as a whole. To others more competent will be left the duty of taking up special fields of his activity.

Like Henry and Baird, Langley came from what in various other lands is known as the middle class, neither burdened by wealth nor crushed by poverty—the class from which come so many leaders in every field.

He was descended from families which settled in New England early in the seventeenth century, and among his ancestors appear skilled artisans, mechanics, clergymen, and heads of schools; among the latter, a president of Harvard College, author of the first American work on astronomy. Among these forefathers of his were abundantly represented robust force, mechanical skill, intellectual vigor, and wide culture; best of all, there was dominant among them a staunch sense of duty, high moral ideals, and an all-consuming pursuit of new truth—often by skillful methods and sometimes upon original lines. They were of those who build or enrich states by conscientious work and sane thought, and not of the proletary immigrants who increase immediate wealth, but bring and spread social disease.

He was born on August 22, 1834, in Roxbury, Mass.; was in due time sent to various private schools, and later to the Boston Latin and High Schools, where he was given what was then known as a

good academic education, including a large admixture of Latin grammar, which probably did much to train his boyish judgment.

Noteworthy, in the sketch which he wrote during the last hours of his life, is the statement that his father, a wholesale merchant in Boston, owned a telescope and that with this the boy roamed among the starry hosts and also watched the building of the Bunker Hill Monument. From his childhood he devoured books of all sorts; loved art; traveled, in spirit, through foreign lands; reflected much and curiously on his reading and on the world about him, but concentrated his studies mainly upon mathematics.

Under the early necessity of looking to his livelihood, he did not enter college, but studied civil engineering and architecture in ways most accessible to him, these professions best according with his tastes and aims.

At the age of twenty-three he went westward, and spent the next seven years mainly in Chicago and St. Louis, devoted to his profession and successful in it, thereby gaining a modest competence, with business training and a skill in drafting which proved of great value in his later career, scientific and administrative.

In 1864, at the age of thirty, he definitely abandoned his profession and, having returned to New England, spent some time in building telescopes—several refractors, and finally a reflector—which took his spare time for three years. Later, with his brother, John Williams Langley, he gave something more than a year to European travel, visiting, especially, scientific institutions, observatories, and galleries of art, thus showing the trend of his tastes, which thereafter steadily turned toward astronomy as a profession and toward the fine arts as a pleasure. During this journey he gained a good knowledge of the continental languages, especially of French, in which he finally acquired notable proficiency as a reader, writer, and speaker.

Upon his return he seems to have assumed a position in American science in a way at first sight mysterious. He had as yet not published anything of note; had not made himself known in the universities; had made no popular addresses; had not pushed himself into notice in any way; yet there was in him something which attracted strong leaders in science, inspired respect, won confidence, and secured him speedy advancement.

His promotion was rapid. First, to an assistant's place in the Harvard Observatory; two years afterward, to a professorship of mathematics and the practical direction of the observatory at Annapolis, and less than a year later, at the age of thirty-two, to the

professorship of astronomy and physics at the Western University of Pennsylvania, at Pittsburg, with the directorship of the Allegheny Observatory—a position which he held for twenty years.

Arriving at Pittsburg, he was confronted by obstacles which to a man not trained as he had been would have probably proved insurmountable. He found there, for his work, an equatorial telescope of good size, used by an amateur club mainly for simple star-gazing, but not equipped for scientific work; and beside this virtually nothing—no transit instrument, not even a clock.

There was little chance for him to be helped over these obstacles by private munificence. Since that time there has appeared a galaxy of millionaires who have endowed Pittsburg with great foundations in science, literature, and art, one of whom, indeed, has created institutions which have aroused amazement and gratitude on both sides the Atlantic; but at the young astronomer's arrival none of these leaders had appeared. He had at once to meet the question how to acquire, mainly by his own skill and toil, the instruments necessary to make the observatory useful.

His insight and foresight gave a speedy answer. He saw quickly that a pressing need of the great lines of railway connecting with Pittsburg, east and west, was a better standard of time. This had been already seen at other American centers, notably at Washington, at Cambridge, at Albany, and elsewhere; but it was only when Langley at Pittsburg grasped the subject, both in its scientific and business bearings, that there came a plan to meet American conditions—useful, practicable, and widely extended. To him more than to any other is primarily due the fixing of railway time standards in the United States. The clock at his observatory finally gave, twice a day and automatically, the exact time to every station on lines extending for eight thousand miles.

He saw not merely the need of devising a system of time standards, but the practical methods of realizing it. He also made the busy men about him see this need and grasp his methods, and from them, in their own interest, he obtained the equipment of his observatory.

In 1869 he published his first two papers which attracted attention, the first being a brief report upon his observation of the total eclipse at Oakland, Kentucky, and the second "A proposal for regulating from the Allegheny Observatory the clocks of the Pennsylvania Central and other roads connected with it." Thus came from him, characteristically, a contribution to astronomy as a science and the satisfaction of a public need.

He now steadily pressed on in both these directions. As to scientific astronomy, his resourceful work while in charge of the Coast Survey party, observing the eclipse of 1869 in Kentucky, led Professor Winlock of Harvard to invite him to join the Government expedition for observing the eclipse of 1870 in Spain, and as to observatory work applied to practical affairs, he published, shortly after his return to America, an article in the *American Journal of Science,* proposing a more complete transmission of time, not only to railways, but to makers and regulators of clocks and watches in various city centers.

About the year 1873 he concentrated the purely scientific side of his work upon observation and study of the sun. He had for some time previously given all attention possible to this field, and now for seven years he was engaged in minute telescopic study and in drawing the details of the sun's surface, and especially of sun-spots. This demanded, first, intense and long-continued observations; next, genius in catching the essential phenomena; and, finally, infinite patience in recording them. Photography had not yet been pressed into the service of such work, and his skill and accuracy proved of special value. Astrophysicists still declare that his drawings made at the Allegheny Observatory prior to 1875 are even now to be regarded as among the most trustworthy evidence regarding the sun's surface, and to this hour the standard illustration of a sun-spot which appears in most of the astronomical textbooks is the one drawn by Langley with his own hand in 1873.

Since that time vast progress has been made in this work; but we have the authority of Professor Hale, who has since advanced astrophysics by the aid of the forty-inch reflector of the Yerkes Observatory and of the Carnegie telescope on Mount Wilson, California, that, in his own observations of sun-spots, the better they have been seen, the more nearly have they appeared as in Langley's drawings.

In 1875 Langley's researches went deeper, and he began to concentrate his thought and work upon the measurement of the heat spectra of the sun and other sources of radiation; but here, too, he had to break a way through obstacles. No heat-measuring apparatus known up to that time could enable him to discriminate accurately between the temperatures of various narrow portions of the spectrum; the thermopile, which was then the main reliance for the closest observation in this field, was utterly inadequate; he must invent new instruments; and in 1879 and 1880 he produced his invention of the bolometer.

This was a vast advance upon all previous instruments for the

purpose; it finally enabled him to measure differences in temperature less than one-hundred-thousandth of a degree centigrade, and it proved to be the precursor of instruments giving even a more astonishing degree of accuracy. It was speedily applied by astronomers and physicists in wide ranges of experimental work, and in Langley's hands was used from the time of its invention down to the last days of his life, especially in opening up a great new field of investigation in connection with the invisible long wave-length rays proceeding from heated bodies, and has been a main means of developing a new science of these.

The more important of his many researches published in the period which now began were upon the Energy Spectrum of the Sun, the Transmission of Light through the Earth's Atmosphere, the Solar Constant, the Behavior of Prisms toward long Wave-Lengths, the Energy Spectra of Heated Terrestrial Bodies, and the Energy Spectrum of the Moon. Hitherto the moon's heat had been recognized with difficulty, even in gross, by the thermopile; but now, by the bolometer, it was analyzed in minute detail, in a lunar heat spectrum. All this suggested later a comparison of the proportion of luminous and non-luminous heat in the spectrum of the sun and artificial light sources and a multitude of supplementary researches.

During the summer of 1878 he took charge of a party sent out by the United States to study from Pike's Peak the total eclipse of that year, and was able to follow the sun's corona to a distance from the main body hitherto unsuspected; during the winter of the same year he visited Europe and followed up these observations by others upon Mount Etna.

In 1881, through the generosity of citizens of Pittsburg and with the coöperation of the United States Signal Service, he conducted an expedition to Mount Whitney, the loftiest mountain in southern California, and among the pregnant results of his observations was a volume which established the present view regarding the selective absorption of the sun's light by our atmosphere. These researches, being presented in a brief minor paper and an extensive memoir, attracted wide attention both at home and abroad.

In 1885 he had followed the actual solar spectrum to wave-lengths ten times as great as those of the visible spectrum.

Subsidiary to these researches were those upon the optical characteristics and possibilities of rock-salt, thus developing most usefully Melloni's experiments with this substance in his epoch-making researches nearly a hundred years before.

The reputation thus gained by Langley came rapidly and increased steadily. The thoroughness, ingenuity, and beauty of his methods

and the clearness of his style in presenting them attracted attention far and wide.

In the autumn of 1886 he was invited to the post of Assistant Secretary of the Smithsonian Institution. In the invitation Professor Baird, the Secretary at that time, assured him that, while in his new post he would be expected to take charge of the foreign and domestic exchanges, the library, and publications, fully half of his time might be employed, to use Professor Baird's own words, in "keeping up those original researches at Allegheny Observatory which have already secured for you so much distinction in the scientific world." The invitation was accepted, and after the death of Professor Baird, in August, 1887, Mr. Langley was elected by the Board of Regents Secretary of the Smithsonian Institution.

From the beginning of his life in Washington he gave especial thought to the exchange service, the library, and the publications, and ever retained a deep interest in these. To his mind, the exchange system was a main means of carrying out Smithson's bequest "for the diffusion of knowledge among men," and the publications were no less essential in accomplishing the founder's purpose of "increasing knowledge." Noteworthy, especially, is the fact, also, that Doctor Langley exerted himself constantly to see that the reports were, as far as possible, free from unnecessary technical terms and prepared in a language which could be understood by every man of ordinary education and intelligence.

His activities in behalf of the Institution were extended in many ways, but he evidently felt that, apart from these, his main function was to "increase knowledge" in the new department to which his special astronomical researches had been mainly devoted. To this end he established, under the direction of the Smithsonian Institution, an astrophysical observatory, the means for that purpose being due, first, to the generosity of the late Jerome H. Kidder and of Mr. Alexander Graham Bell, and later to appropriations by Congress. The sum required was not a heavy burden on the public purse, but after a few years, a question as to the usefulness of this observatory having been raised in Congress, a committee was appointed to examine and report upon it. This committee communicated with the foremost men of science in our own country and in Great Britain, who were entitled to pass judgment on Doctor Langley's work. The expressions of these eminent astronomers were uniformly favorable, and can best be summed up in a single declaration by Sir William Thompson, now Lord Kelvin, that in the special and

very important province of measuring the heating power of the sun through the enormous range of wave-lengths included in Doctor Langley's observations, his work was unique, and that it would be profoundly regretted by the scientific men of all countries if anything were to occur to check its vigorous prosecution or to diminish the resources of the Astrophysical Observatory of Washington for work of any kind in its province. The result was that Congress continued the appropriation for the maintenance of the observatory, and its wisdom in doing so no thoughtful man who has reflected upon the history of science can doubt. For if there is anything which history teaches, it is that every important scientific truth may be translated into useful activity for mankind.

There can be no doubt in the mind of any competent thinker in this field that from Doctor Langley's researches with the bolometer, the photographic plate, and various instruments of accurate mechanism devised or perfected by him will date discoveries of vast import, not merely to scientific investigators, but to the world at large. His first discoveries are sure to be written in the history of the nineteenth century as among the real glories of our country. They combine profound original research, exquisite ingenuity, and a large, philosophic view of the relations of his work to that which had gone before and that which was sure to follow.

But, while carrying on these original researches in his principal field, his fertility of thought was seen in other directions calculated to benefit his fellow-men. He did not fear to endanger his reputation as an original investigator by spreading scientific knowledge in various forms among the people at large, and in terms not merely intelligible, but attractive. Courses of lectures and articles in magazines addressed to men and women of various attainments testify amply to this. Some of these rose into the higher regions, not only of science, but of literature. Notable especially was his address in 1888, on retiring from the presidency of the American Association for the Advancement of Science. It was entitled "The History of a Doctrine"—this doctrine having relation to radiant energy. Both in thought and style it is a masterpiece and it reveals the mind of a philosopher. Many passages give contributions to philosophic thought, but I select one, which runs as follows: "We have, perhaps, seen that the history of progress in this department of science is little else than a chapter in that larger history of human error which is still to be written;" but he adds: "Shall we say that the knowledge of truth is not advancing? * * * It *is* advancing, and never so fast as today; but the steps of its advance are set on

past errors, and the new truths become such stepping-stones in turn."

Noteworthy, also, were certain lectures, more or less popular, at the Stevens Institute at Hoboken, at the Lowell Institute at Boston, at the Peabody Institute at Baltimore, and before various bodies in Pittsburg, and his publications in the *Pittsburg Gazette,* in the *Century Magazine,* and later still in a book which has gone through several editions under the title of "The New Astronomy." These lectures and publications set clearly before educated people the results of his own labors and those of others in that astronomy which deals primarily not with the existence and movements of the heavenly bodies, but with their constitution. The spirit in which it was written can be gleaned from its very brief preface:

"I have written these pages," he says, "not for the professional reader, but with the hope of reaching a part of that educated public on whose support he is so often dependent for the means of extending the boundaries of knowledge.

"It is not generally understood that among us not only the support of the Government, but with scarcely an exception every new private benefaction, is devoted to 'the old astronomy,' which is relatively munificently endowed already; while that which I have here called 'the new,' so fruitful in results of interest and importance, struggles almost unaided.

"We are all glad to know that Urania, who was in the beginning but a poor Chaldean shepherdess, has long since become well-to-do, and dwells now in state. It is far less known than it should be that she has a younger sister now among us, bearing every mark of her celestial birth, but all unendowed and portionless. It is for the reader's interest in the latter that this book is a plea."

The importance of this book was due, first, to its sterling scientific qualities, but also, in a marked degree, to its style and spirit. It is not too much to say that its literary character is unsurpassed by the work of any other American scientist, and deserves to be ranked with the popular scientific expositions of Darwin, Wallace, Huxley, and Tyndall.

Nor were publications of this sort at all detrimental to his research work. During this whole period, even from as far back as 1875, his original contributions to advanced science were recorded in the most eminent foreign journals, and among these especially in the transactions of the Academy of Physical Sciences of the French Institute.

Remarkable, as a tribute to his skill both in seeking and in

spreading knowledge, was an invitation to give a course of lectures before the Royal Institution of Great Britain. These lectures, with various communications to learned bodies, and especially to the Institute of France, increased his international reputation, which took shape in a most remarkable series of honors.

A brief summary of these shows the high place which his name holds in the annals of science:

From Oxford came the degree of D. C. L.; from Cambridge, that of D. Sc.; from Harvard, Princeton, Michigan, and Wisconsin universities and elsewhere, that of LL. D.; from the American Academy of Sciences, the Henry Draper Medal; from the Royal Society of London, the Rumford Medal; from the American Academy of Arts and Sciences, their Rumford Medal; from the Institute of France, the Janssen Medal, and from the Astronomical Society of France, their special medal. He was made a foreign member of the Royal Society of London, a corresponding member of the Institute of France, a fellow of the Royal Astronomical Society of London, a member of the Royal Institution of London, of the Academia dei Lincei at Rome, of the National Academy of Sciences, and of other bodies eminent in the scientific world.

In the midst of these honors, gained by original investigation, his feeling in behalf of the popularization of science continued, and one of its manifestations gives a curious revelation of his heart. Quiet, undemonstrative, reserved as he was—even to a fault, as many thought—and even though he had no family of his own, he had a deep love for little children, and this love was shown in a way most effective and original. He provided in the Museum of the Smithsonian a room containing objects in various fields of natural research which would please children and awaken their interest. Even this room showed his ingenuity; it became deeply interesting not merely to the children, but to their parents and grandparents, and to widen this interest he published an article—of all places in the world—in the *St. Nicholas Magazine,* in which he appears as an attorney for the children against the more staid devotees of science.

His devotion to the welfare of his countrymen at large carried him still further. He was one of those who believe that the highest interests of this Republic are served by making its capital city more and more dignified, noble, beautiful, and attractive. During the later years of his life it was his custom to make an annual visit to Europe in order to study the latest progress made, not only in science, but in art, and the feelings thus strengthened he brought back to his own country. One manifestation of these was seen in his zeal

for the National Park at Washington, and for the Zoölogical Garden which forms part of it; another in his desire for a National Museum worthy of a great republic; and finally, most of all, toward the close of his life, in his efforts—which were finally successful—to make a beginning of a museum of art. It is, perhaps, due Langley's fame, and even his good name, to say that his steady effort to overcome the legal and legislative difficulties in the way of bringing the Freer collection to the Smithsonian was carried on uncomplainingly in the midst of attacks by the press upon him and upon the Regents for "neglecting so important a matter."

In these latter activities he departed somewhat from the policy of the great man who first marked out a course for the Smithsonian Institution, Joseph Henry, and from the theory and practice of his immediate predecessor, Spencer Baird. All three of these men were right. It was most fortunate that Henry, during the first years of the Institution, insisted on rejecting a multitude of projects, each attractive, but which, had they been adopted at that early period, would have initiated policies distracting and possibly mutually destructive. But when Langley showed his willingness to bring the Smithsonian into additional relations with the deep feeling of thinking Americans that our capital city should be made worthy of the Republic, all danger of departure from the intentions of James Smithson was past. The great line of policy which Smithson suggested, which Henry founded, which Baird and Langley continued, was secure, and the breadth of Langley's mind led him to see that the Smithsonian Institution could now be made the center for a *new* "increase and diffusion of knowledge" among his own countrymen which up to his time it had not been wise to undertake.

And here should be mentioned a characteristic which distinguished him in a striking way from both his predecessors. Each of these was a strong man, even a great man, in the branch of science which he had chosen. But neither of them had any striking enthusiams outside of science. With Langley it was otherwise. Eminent at home and abroad in a new and fruitful branch of scientific research, he had various other enthusiasms and a greater breadth of view than had either of his predecessors. He loved art with a deep and abiding love, and was competent to discuss it in its highest manifestations. History and literature he had so thoroughly studied in some of their most fruitful fields that he would have done honor to any institution in the land as a professor in them. In various periods of English history and literature he had made studies which led competent authorities, at no less a literary center

than Oxford, to consult him. In sundry interesting fields of German literature he had also wrought to good purpose. Most of all, he had, by close study and thought, realized the deep meanings of important phases of French history.

Here I may be pardoned for a personal reminiscence:

At the height of Doctor Langley's activity in scientific research, I was honored with an invitation to deliver a course of lectures in this city, on "The Causes of the French Revolution." Most unexpectedly, I found Doctor Langley among my auditors at every lecture. To my still greater surprise, I found in my walks and talks with him that he was competent to discuss, as a master, the whole subject with which I dealt. I particularly remember his minute and accurate knowledge of the comparative value of sundry authorities, and it is only justice to say that I had reason to be deeply indebted to him for suggestions regarding them. It was not merely that he had read works of importance in the history of the period concerned, from the statesmanlike judgments of Thiers to the prose poem of Thomas Carlyle, but that he had gone extensively into original sources, and especially into the multitude of memoirs, which throw so remarkable a light into the causes of the fact that the vast change which has been taking place in France during more than a hundred years came not by a steady, healthful evolution, but by a terrific revolution.

He had indeed personally known Carlyle and was clearly influenced by the great Scottish prophet's theory regarding great men as the centers of historical development. A long range of historical personages in various countries had especially interested him, and among these Leonardo da Vinci, Cromwell, Frederick the Great, Louis XIV, Napoleon, and Lincoln; upon these he had read extensively and thought deeply.

And he went yet further afield. Curious is the fact that, visiting Tahiti in 1901, he became especially interested in what, to most travelers, would appear a mere piece of clumsy jugglery, but which he recognized as a survival from the early history of our race, namely, the power acquired by certain persons to withstand intense heat, or to appear to withstand it. As a result, he published an exceedingly interesting contribution entitled "The Fire Walk Ceremony in Tahiti," thus throwing light into the history of the ordeal, which plays so great a part in the early history of human law, both as regards procedure and penalty.

But he soared into wider and broader realms—into studies of the metaphysicians and of the modern psychologists—associating himself with societies for psychical research. He seemed to attempt all

the difficult problems which were offered in his time to human observation or curiosity. One of his most intimate friends, Dr. Cyrus Adler, to whom I am greatly indebted for details of Langley's life, tells us that he loved to talk with men of positive religious views about their own beliefs, and took a deep interest in a Jesuit, or a Jew, or a Buddhist, or a Mohammedan, or, indeed, in any man who thought he had secured any truth and knew the way of life in this world or in the world to come. His paper on "The Laws of Nature" is a very significant revelation of this characteristic—melancholy at times, but suggestive of broader ranges of thought than those bounded by the orbits of the greater number of skeptics.

Nor was all this at the expense of his scientific, artistic, or practical qualities.

Being with him in Paris some years since, I learned from him his hope that a great collection, made with large resources, special ability, and long-continued care—a collection which illustrated an important field of industrial endeavor and at the same time some interesting fields in art—was in the possession of an American then residing in that city, who in various conversations had shown a willingness to have it pass under some public custody in the United States.

Doctor Langley's discussions of this collection, of its bearings both on art and industry, of the appropriateness of such a destination, of the place which it might occupy in the Smithsonian Institution, showed a breadth of view and a fertility of resource in practical matters which left nothing to be desired. His arguments were absolutely convincing, and it is through no fault of his that the arrangement which he proposed has not yet been consummated, and none the less does his earnestness in behalf of an exhibition which would have benefited not merely Washington, but the whole country, deserve commemoration.

It may be thought that this popularizing of scientific results, this zeal in fields which his predecessors had thought mainly outside of the true scope of the Smithsonian Institution, this broad love for literature, art, and general science, this passion for investigating remote and even strange subjects of thought, this zeal for attaching to the Smithsonian Institution anything of value in any field, would weaken his power for fixing his mind upon his main subjects of investigation. Not so; not at all so. These studies outside his main work certainly revived him and gave him new energy. Again and again he came back to original researches and studies in his own field of science which showed all his old fertility and ingenuity.

Among these may especially be noted his "Report on the New Spectrum," his study on "The Personal Equation," his discussion on "Good Seeing," his paper on "The Observation of Sudden Phenomena," and the intensely interesting article on "The Cheapest Form of Light," this latter study being based upon the radiations from the glow-worm and firefly, showing that these produce light virtually without heat, and that this being actually effected by nature may possibly yet be effected by science.

I come finally to another field of Doctor Langley's work, one with which his name was identified during the last fifteen years of his life—the subject to which he applied the name aërodynamics. His first communication to the scientific world and to the public generally took the shape of a very brief letter to the Academy of Sciences of the Institute of France, in July, 1890; also by a publication of an extended memoir in the Smithsonian Contributions; and, thirdly, through a brief popular article on the possibility of mechanical flight, published in the *Century Magazine*. I have spoken regarding the group of great leaders in industrial enterprise at Pittsburg, and the name of one of them was now commemorated in the preface of Langley's "Experiments in Aërodynamics," as follows:

"If there prove to be anything of permanent value in these investigations, I desire that they may be remembered in connection with the name of the late William Thaw, whose generosity provided the principal means for them."

This memoir was at once published in French, and Doctor Langley followed it, in 1893, by a second study, "The Internal Work of the Wind," which also appeared in English and French, and which was designed to prove that aërial flight had an aid in the laws of nature, hitherto little, if at all, known, which would be of great moment in the practical solution of the problem.

But the painstaking experiments with the whirling-table and with other forms of apparatus devised by Doctor Langley for the study of this question did not content him, and he began the building of a machine driven by a steam-engine which he hoped would practically demonstrate the possibility of mechanical flight. There were innumerable mechanical difficulties, both in its construction and its launching, and after failures which would have disheartened most men, a large measure of success came in the spring of 1896, when a steam-driven aërodrome constructed under Doctor Langley's direction, in his own shops, engine and all, actually flew over the Potomac River for three-quarters of a mile.

This success had world-wide recognition. It was communicated

to learned bodies; it was spread abroad by the newspapers, and in an article published in *McClure's Magazine* Doctor Langley himself described this trial and told how he came to enter upon the subject. From his own words we learn that this had been a problem with him from his childhood; that in his early days he used to lie on his back in a New England pasture, watching the hawks soaring far above him, sailing for a long time without any motion of their wings, and suggesting questions which were renewed during his mature life, and which finally set him at seriously inquiring whether the problem of artificial flight was as hopeless and absurd as it was thought to be: "If Nature has solved it, why not man?" This article, published in 1897, closed with the following paragraphs:

"I have thus far had only a purely scientific interest in the results of these labors. Perhaps if it could have been foreseen at the outset how much labor there was to be, how much of life would be given to it, and how much care, I might have hesitated to enter upon it at all. And now reward must be looked for, if reward there be, in the knowledge that I have done the best I could in a difficult task, with results which it may be hoped will be useful to others. I have brought to a close the portion of the work which seemed to be specially mine—the demonstration of the practicability of mechanical flight; for the next stage, which is the commercial and practical development of the idea, it is probable that the world may look to others."

It must not be supposed that Langley, even during *this* period, dropped his astrophysical work. He steadily thought upon the improvement of his instruments, and through such improvements produced invaluable results. The bolometer was brought to a greater degree of refinement than had ever before been attained, and the work under his direction had progressed during this period to such a point as to justify the publication of a remarkable volume of Annals and an expedition to observe the solar eclipse of 1900, at Wadesboro, North Carolina, in which he was remarkably successful. A half dozen or more papers illustrating the various advances made in the study of the spectrum were also issued about this time.

But while this, which he considered the great work of his life, was going on he was led, in 1898, through circumstances which are not definitely known, but which had to do, to a certain extent, with the Spanish-American War, to take up the building of a flying-machine of such power as to carry a man, this work being undertaken under the Board of Ordnance and Fortification of the United States Army and with an allotment made by that board for the pur-

pose. It is clear that in this matter he was led by a sense of patriotic duty, for, as we have seen, he had virtually announced his intention, in his work on Aërodynamics, not to carry his own work in flying-machines further, but to leave it to others.

He may also have been influenced by the fact that since the successful flight of the first aërodrome, in 1896, a further possibility of increased power with comparative lightness had come with the employment of the gas engine. A brief popular account of the subsequent experiments with the Langley aërodrome under these new conditions appeared in 1905, but no extended memoir on the subject has yet been published. In this popular account Doctor Langley describes the difficulties and discouragements met with in building the new machine, and finally in the trials of it. The launching of the test models had given a success which greatly encouraged him, but the launching of the large machine, first on the 7th of October, 1903, and again on the 8th of December of the same year, was not, apparently, successful.

Although the decision of the general public was unfavorable, Doctor Langley

"——bated not one jot of heart or hope."

He insisted that, despite the failure in launching, there had been no error detected in the principles he had relied upon or in the main means of making them effective, and that the practical problem was in a fair way to solution.

But there can be no doubt that, in spite of this continued faith in the agencies and means employed, this failure in the machinery was a serious blow to him—not so much because of the failure itself, for he knew well that in the history of science great successes have come most frequently after repeated failures. Had the experiments failed in his laboratory or workshop, it would not have affected him; but it was impossible to make them save in the open air, before the whole world. His arrangements with the Board of Ordnance and Fortification absolutely required that the details of the construction should not be made public. The newspaper press of the country, insisting upon information, misunderstanding his motives, and angered, possibly by the large expense connected with maintaining special correspondents at an inconvenient place on the Potomac River, possibly also by Langley's greater anxiety for the outcome of his experiments than for the comfort of the correspondents, finally united in a chorus of ridicule and attack, which in time made itself felt in the national legislature. His great repu-

tation—at home and abroad—seemed butchered to make an American holiday. At his years, for he was then nearly seventy, all this, despite his optimism, deeply affected him.

And here should be considered for a moment the lack of means to which he referred in one of his statements. It was a lack of means from the source from which he thought he was entitled to obtain them. An absolute lack of means there was not. Private individuals offered him the means to continue his work. Several years before this he had been offered a considerable sum for this work if he would but place it upon some commercial basis, and take out patents on such portions of the machinery as were patentable, in order that commercial reward might come to the persons furnishing the money; but he steadfastly refused either to secure a patent or to accept money from private persons as a matter of business. He declared that his work was solely in the interest of the nation, and if the nation was not prepared to support it, he was not willing to proceed with it.

No one can deny that the stand he thus took was honorable to him—as honorable as was the similar stand taken by his great predecessor, Doctor Henry, regarding his discoveries and inventions in electro-magnetism, which, had they been patented, would have brought him wealth.

Interesting is it that a verdict was rendered upon these later experiments by a body of thoughtful and practical students in aërodynamics, who, after a series of meetings in the city of New York, adopted resolutions expressing their high estimation of Doctor Langley's contributions to the science of aërial locomotion and of his successful efforts in solving some of the most difficult problems involved; and it is consoling to know that this, the last official paper laid before him, gave him comfort upon his death-bed. We may well rejoice that in his last hours he received this testimony of confidence from a most competent source as to his theoretical success, and as to possibilities and even probabilities of ultimate practical success.

It remains now to make brief allusion to some of his personal characteristics—to his daily life as the world saw it.

It cannot be claimed that among the great body of younger men devoted to science he ever aroused any such general affection as they had bestowed upon his immediate predecessor. Respected Langley was—universally and widely; popular, in the usual sense of the word, he was not. Yet there were not a few among his compeers who not only revered, but loved him. As regarded the world at large, even

as regarded scientific workers in the mass, he was reserved, and even shy. His mind seemed so concentrated upon the problems immediately before him that there came an aloofness from much of the work of others. But many there are who can testify to the warmth of his sympathies and to his tenderness of heart. To those who stood nearest to him, it was well known that from the loss of his friends, Doctor Brown Goode and Professor Winlock, he never entirely recovered.

Though yielding often to the demands of society and always a welcome guest, he lived in remarkable seclusion, not accessible in his own home save to very few. With no close family ties of his own, he was especially attracted by the friendship of children, and were it not to reveal utterances too sacred for an occasion like this, I might speak of most tender and pathetic evidences of this friendship.

He had, as an inheritance from his New England ancestry, a strong sense of duty, which was expressed at times with more directness than tact.

His mind was very frequently so absorbed in various fields of science, literature, and art that he seemed to become forgetful or indifferent regarding much valuable work which went on about him.

In his scientific aspirations there was not infrequently a tinge of melancholy akin to that shown by so many eminent investigators, including Bacon and Newton.

His religious instincts were highly developed, but in a different way from that seen in either of his predecessors. No utterance ever came from him on the subject of his religious belief so precise as the well-known letter written by Doctor Henry shortly before his death. Neither was there the quiet acquiescence in dominant religious ideas shown by Professor Baird. Langley was from first to last an ardent seeker for religious truth, and, as is especially shown in some of his writings, equally hostile to dogmatism against and in favor of received opinions.

A self-seeker he never was. His labor, his thought, his efforts in every field, had as their one object the establishment of truth as truth. For he had high aspirations and a deep faith—aspirations toward the best that humanity can receive, and faith in the truth that makes mankind free.

THE SCIENTIFIC WORK OF SAMUEL PIERPONT LANGLEY.

BY PROF. E. C. PICKERING.

THE CHIEF JUSTICE: I am gratified, ladies and gentlemen, to present a gentleman, with whose reputation you are all well acquainted and who was associated years ago in eclipse expeditions with Mr. Langley—Professor Pickering, Director of the Harvard Observatory.

PROFESSOR PICKERING: Mr. Chief Justice, ladies and gentlemen: In comparing the paper we have just heard with that I am about to read to you, you will probably be impressed, as I have been, with the manner in which two minds, in dealing with the same facts from wholly different standpoints, have arrived so closely at the same results. Possibly this coincidence may justify us in the belief that these facts are really the most important in Langley's career. The fact that they should have impressed one whose mind has been occupied by such different lines of work from those of Langley I think also justifies me in the very high degree of value I attach to them in the paper which I am presenting to you. Possibly when you have heard my paper you may suspect that in some respects Doctor White and I have interchanged the subjects which were assigned to us.

The scientific work of Samuel Pierpont Langley extended over a period of forty years, and occupied his entire strength and energy during a large part of this time. It is evidently impossible to do justice to such a subject in the time allotted to me this evening. Fortunately, he lived to publish his most important work and thus make it known to the world. Admirable reviews of it have also recently appeared in the technical journals, recalling it to the professional physicist and astronomer. It remains for me to tell you how it appears to one who knew him well during nearly this entire period, who prized long discussions with him regarding his work during his earlier years, and whose affection and friendship for him never waned and were interrupted only by his death.

His work in science naturally divides itself into two parts, one while Director of the Allegheny Observatory, and the other while Secretary of the Smithsonian Institution. Each of these extended over a period of about twenty years, and was conducted in surroundings differing in almost every respect. His remarkable skill as a

draftsman led him first to an architect's office. A year later he was appointed assistant in the Astronomical Observatory of Harvard College, and his interest was thus permanently directed to this department of science. The first problem assigned him was the study of the great Trifid Nebula in Sagittarius, a research in which his unusual combination of artistic skill and precise methods proved as useful to him as in some of his later work. The first discovery he made was two faint stars near the remarkable triple star in this nebula. The next year found him teaching in the Naval Academy, as Assistant Professor of Mathematics, and in the following year he was appointed Director of the Allegheny Observatory. This position was regarded by his associates as an extremely desirable one. Although under the control of the University of Western Pennsylvania, no teaching was required. The liberality of the founder, the late William Thaw, permitted the entire time of the director to be devoted to research—a privilege then enjoyed by but few American astronomers. His early years at Allegheny were not free from incident. His predecessor became insane, and wrote a poem about the large telescope which he appeared to worship. He objected to the presence of other persons in the dome and emphasized his views with a shotgun. In his poem he predicted the disappearance of the lens, which by a singular coincidence came true, although it appears to be certain that he had no connection with the theft. Mr. Langley tactfully got into communication with the thief, and his account of their interview was graphic. Walking up and down under the trees one evening in a secluded spot, the thief remarked, "You are a gentleman and I am a gentleman; we can trust one another." The lens was finally returned without the reward which was offered for the conviction of the thief.

There was only one disadvantage to Langley's position, the lack of appreciative friends interested in his work; but it was a serious loss to a man of his social disposition. To offset this, it gave him abundant leisure, which he employed to good advantage, as he was an omnivorous reader. There was a grain of truth in his witty reply to an admiring young lady, who remarked, "Why, Mr. Langley, I do believe you have read every book that ever was written." "Oh, no," he said, "there are six that I have not read, as yet." He thus attained a cultivation that more than made up for his lack of a college education and gave him a remarkably large vocabulary. It was perhaps through these conditions that he acquired a charming style, which rendered his "Old and New Astronomy" one of the most enjoyable works on the subject. His first contribution to a

scientific periodical was on "A New Form of Solar Eyepiece," and it is characterized by a careful study of practical detail. It is evidently the work of one who had laboriously constructed the instrument, overcoming its early defects by careful trial, and not that of a student who suggests a new method by theory alone. His second article, "On the Allegheny System of Electric Time Signals," is also a remarkable one. All the trains of the great system of the Pennsylvania Railroad were run for many years on time furnished by him. His method of furnishing and distributing time was one of the first and one of the best that has been adopted. Its introduction provided an important addition to the resources of the observatory. He now entered upon serious scientific work. The dense smoke of the adjacent city of Pittsburg rendered observation of the stars difficult, and he wisely selected the sun as a subject for study. In this work the smoke, in some respects, proved to be an advantage, since it cut off the heat and rendered the image of the sun steadier than in a clearer atmosphere. From 1874 to 1890 he was a frequent contributor to the scientific journals, sending to them an average of about three articles a year. His early studies related to the structure of the sun, and his artistic skill enabled him to produce the finest engraving ever made of the marvelously complex structure of a sun-spot. He took part in eclipse expeditions in 1869, 1870, 1878, and 1900. His studies of the sun at first related to its structure, but later to its spectrum. Recognizing the limitations of the human eye, he endeavored to find a substitute for it, and this led to his invention of that wonderfully delicate instrument, the bolometer, through which his name is best known to the scientific public. It is easy to render the principle of this instrument clear, even to those unfamiliar with science, but difficult even for the professional physicist to realize the immense care and labor required to bring it to its final perfection. Whatever may be our belief regarding the nature of a current of electricity, there is no better way of describing some of its properties than to go back to the time of Franklin and treat it like a current of water. Suppose, then, that two pipes, laid side by side, are carrying water from one vessel to another, and that they are connected at their centers by an intermediate, or cross, pipe. If the two principal pipes are exactly alike, evidently there will be no flow through the cross-pipe; but even a slight obstruction of one will cause some of its water to pass through the cross-pipe into the other pipe. Substituting electricity for water, we have Wheatstone's bridge, of which the bolometer is a modification. A delicate galvanometer is substituted for the cross-pipe, and an excessively

small amount of electricity flowing one way or the other is thus detected. If one of the wires carrying the current is heated, its resistance is increased and the equilibrium disturbed. Heating the other wire by a known amount, we may be sure that the two quantities are equal when the galvanometer shows that no current is passing. This gives but little conception of the years of work Langley spent in improving the instrument in every detail, and which finally led to a wonderful delicacy, so that in 1901 he stated that a change in temperature of one-hundred-millionth of a degree Fahrenheit was perceptible. The presence of a cow in a pasture could be detected by the heat she radiated, even at a distance of a quarter of a mile. Langley was thus placed in possession of an instrument of unheard-of delicacy. At Allegheny, and later at Washington, the use he made of it was good indeed. The heat of sun-spots, of different portions of the sun's disk, the temperature of the moon, the absorption of the earth's atmosphere, and the effect of elevation represent in each case months or years of careful and laborious work. Probably his most important research was the extension of the red end of the solar spectrum. Far beyond the limits of the eye, he found rays greatly surpassing in energy those of the visual spectrum. With infinite care he traced the spectrum, step by step, recording hundreds of gaps, or dark lines, until he reached a point whose wave-length was $5.3\,\mu$, or seven times as great as that of the dark red rays which form the limit to the eye. But the intensity of these rays, previously only vaguely known, is so great that ninety-nine per cent of the energy radiated to us by the sun, or other sources of heat, is contained in them, scarcely one per cent consisting of rays visible to the eye.

In the midst of these researches he was called to the position which should be the greatest scientific prize in the country, that of Secretary of the Smithsonian Institution. He would become the scientific adviser of the President of the United States, would be independent of political party, and not even controlled by a department. A Board of Regents, including some of the highest officials of the Government, would enable him to secure for his plans the careful attention of the authorities. His field of work would be so broad as to be limited only to the "increase and diffusion of knowledge among men." As a patron, he would have the Government of the United States, whose aid to certain departments of science has been almost unlimited. Distinguished predecessors, high official position, and the brilliant society he had always desired were united in this position. All these dazzling attractions failed to induce him

to abandon his active scientific work, and he accepted only with the condition that he should also continue his work at Allegheny. This, however, proved to be impracticable; but the establishment of the Astrophysical Observatory in Washington enabled him to devote a part of his time to research. A new problem now confronted him—executive work on a large scale. Here he encountered the difficulty that comes to almost every man who undertakes the charge of a large scientific establishment—a difficulty that will probably harass his successor as it did him. This is the large portion of the income absorbed by current expenses. It is like a boat forcing its way against a rapid stream. Much energy may be expended and no progress made. Now add a little more power, and the gain will be very great. It is the same with any industrial or commercial establishment—after expenses are met, all additional income is clear gain. In almost all active scientific establishments, a slight increase in income will represent a large increase in results. I well remember discussing this matter with him. I pointed out how little of the income was used for the "increase of knowledge among men"—scientific research—and I hoped that by reducing expenses he would greatly increase the output. "My dear Pickering," he replied, "you have no idea how; in a venerable institution like this, we are tied down by precedents and traditions. Every attempt I make to reduce current expenses is met by insuperable obstacles." The remedy came largely by additional appropriations by the Government, and by outside aid, like the Hodgkins fund. When we consider the liberal conditions under which the Smithsonian Institution can become a trustee, it is surprising that rich men have not more freely availed themselves of this opportunity to secure a wise administration of their gifts to science. Langley tried hard to aid departments of human knowledge other than those in which he had always been personally interested. It was a great disappointment to him when such unselfish aims were criticized adversely. The National Zoölogical Park is an excellent illustration of his energy in carrying through a plan having no relation to his own scientific work. The establishment of the Astrophysical Observatory, as stated above, enabled him to continue, under much more favorable conditions, his work begun at Allegheny. His other duties, however, compelled him to delegate it largely to others, and he was most fortunate in establishing here a corps of assistants who developed his methods and extended his work with remarkable success. Not to mention those who assisted him at Allegheny and Washington, and are now living, to have produced an astronomer

like the late James E. Keeler, director of the Lick Observatory, was an achievement of which any man might well be proud.

While much of the work of the Astrophysical Observatory has consisted in repeating and extending the earlier work of Langley, many new problems have been undertaken. A matter in which he was greatly interested during the last years of his life was the variation, if any, in the solar constant. This means possible changes in the heat of the sun itself, which from observation with the bolometer appeared to take place rapidly and irregularly, and to be real and not due to changes in the atmosphere of the earth. It is difficult to estimate the commercial and industrial importance of the effect of such changes, if they exist. The pecuniary value of a study of them, if it led to a means of determining their laws so that they could be foreseen, would be almost incalculable.

The work of Langley may be summed up as that of an eager searcher after truth, a careful and persevering investigator, and one whose life was directed to the extension of human knowledge, not only in lines of theoretical interest, but in those which, if successful, would have the utmost practical value.

LANGLEY'S CONTRIBUTIONS TO AËRIAL NAVIGATION.

BY OCTAVE CHANUTE.

THE CHIEF JUSTICE: I will now introduce, my fellow-citizen, the very distinguished engineer, Mr. Octave Chanute, of Chicago.

Mr. CHANUTE: Mr. Chief Justice, ladies and gentlemen: I have been asked to refer briefly to the late Secretary Langley's contributions to aërodynamics.

Doctor Langley said that the subject of flight had interested him as long as he could remember, but that it was a communication read at the Buffalo meeting of the American Association for the Advancement of Science, in 1886, which aroused his then dormant interest in the subject. The explications of flight then given were so evidently erroneous and there were so many conflicting theories on the subject, that Langley determined to find out for himself, and in his own way, what amount of mechanical power was requisite to sustain a given weight in the air and make it advance at a given speed; for this seemed to him an inquiry which must necessarily precede any attempt at mechanical flight, which was the very remote aim of his efforts. Up to that time there had been a vast amount of specu-

lation as to the rationale of flight, "of the way of an eagle in the air," but the question of power required was in hopeless confusion.

Mr. Langley was then engaged in the study of astrophysics at the observatory in Allegheny, Pennsylvania, and there, in the beginning of 1887, through the liberality of the late William Thaw, the work was commenced by the construction of a turn-table of exceptional size driven by a steam-engine. This served during three years to impel against the air planes and appliances equipped with most ingenious measuring and recording instruments designed by Langley and attached to the arm of this rotating balanced beam. The whole apparatus was very scientific and accurate. The results were published in 1891 by the Smithsonian Institution, under the title of "Experiments in Aërodynamics," and at once attracted great attention and commendation.

These epoch-making experiments probably constitute Mr. Langley's chief title to fame in aërodynamics. To avoid complexity, they were all made upon plane surfaces (which he stated might not be the best form of surfaces for support); but they gave to physicists and to searchers, perhaps for the first time, firm ground on which to stand, as to the long-disputed questions of air resistances and reactions. They established (*a*) a more reliable coefficient for rectangular pressures than that of Smeaton. They proved (*b*) that upon inclined planes the air pressures were really normal to the surface. They disproved (*c*) the "Newtonian law," that the normal pressure varied as the square of the angle of incidence on inclined planes. They showed (*d*) that the empirical formula of Duchemin, proposed in 1836 and ignored for fifty years, was approximately correct; that (*e*) the position of the center of pressure varied with the angle of inclination, and that on planes its movements approximately followed the law formulated by Joëssel; that (*f*) oblong planes, presented with their longest dimension to the line of motion, were more effective for support than when presented with their narrower side; that (*g*) planes might be superposed without loss of supporting power if spaced apart certain distances which varied with the speed; and (*h*) that thin planes consumed less power for support at high speeds than at low speeds. This has been called "Langley's law." It results from the fact that the higher the speed, the less need be the angle of inclination to sustain a given weight and the less therefore the horizontal component of the air pressure. It is true only if the plane alone be considered, without any adjuncts, but it leaves out of the reckoning the head resistance due to the various parts of a complete flying-machine, such as its framing, its hull, etc.

Most important of all, this publication gave the sanction of high scientific authority to a line of investigation theretofore despised and left to "cranks." The brothers Wright, in a private letter, say: "The knowledge that the head of the most prominent scientific institution of America believed in the possibility of human flight was one of the influences that led us to undertake the preliminary investigation that preceded our active work. He recommended to us the books which enabled us to form sane ideas at the outset. It was a helping hand at a critical time, and we shall always be grateful."

In a truly scientific spirit, Mr. Langley gave to others the data and information which he had secured, and it may be well here to quote the closing words of his memoir on "Experiments in Aërodynamics": "I wish, however, to put on record my belief that the time has come for these questions to engage the serious attention, not only of engineers, but of all interested in the possibly near practical solution of a problem, one of the most important in its consequences of any which has ever presented itself in mechanics; for this solution, it is here shown, cannot longer be considered beyond our capacity to reach." And now, fifteen years after those words were published, we are in possession of a solution of a problem which had baffled the ingenuity of man since the dawn of history.

When Mr. Langley became Secretary of the Smithsonian Institution, in 1887, he resumed and extended his experiments in aërodynamics, and the results led him to take up the second stage of the investigation, by endeavoring to show *how* the facts ascertained might be practically applied to artificial flight for man. For this purpose he built from 1891 to 1895 four model flying-machines—one driven by carbonic acid gas and three by steam-engines. With these he encountered, of course, a series of disappointments and failures, of which he has given a most interesting account in the "Aëronautical Annual" for 1897, and thus put others on their guard against the same difficulties.

At last, on the 6th of May, 1896, he had the very great satisfaction of seeing his faith and perseverance rewarded by the celebrated flights of his "Aërodrome No. 5" for a distance of about 3,000 feet. An account of this flight, by Dr. Alexander Graham Bell, will also be found in the Aëronautical Annual for 1897. This was followed on the 28th of November, 1896, by a successful flight of "Aërodrome No. 6," and these performances have been repeated many times since on occasions of which no public accounts have been given. Langley was undoubtedly the first man to produce successful flights of convincing lengths of models with an artificial motor, and he thus

opened the way to others who have since achieved success with man-carrying flying-machines.

Meanwhile, in 1893, he published his celebrated paper upon "The Internal Work of the Wind," based on quite another series of experiments. He showed in this that the irregularities of the wind were very much greater than theretofore supposed; that they could be utilized as a source of power, and might account for the soaring upon outstretched, unflapping wings of certain species of birds. It is believed that further reflections and computations convinced him that these irregularities of the wind were probably not sufficient to account fully for soaring flight. They doubtless are utilized on occasion, but the main source of the power to soar and to overcome the wind more probably comes from the rising trends which exist in the air.

It would have been far better for Mr. Langley's happiness and reputation if he had terminated his experimenting with the demonstration, in 1896, that artificial flight was possible. He had made a steam-engine fly nearly a mile, he had elucidated the general principles, had given some data for computing the resistance and the power required, rescued the subject from general disbelief in possible success, and placed the inchoate art upon firm ground. Here it would have been preferable for him to stop, merely publishing such additional data as he had gathered, so that they might be used by others; for few scientists possess the double faculty of investigating the basic principles and of then applying them to produce practical results.

In 1898, however, a board of United States Army and Navy officers recommended that a full-sized man-carrying machine should be developed for war purposes. The Board of Ordnance and Fortification of the United States Army made an allotment of $50,000 for that purpose, and Mr. Langley agreed to supervise the work without any remuneration to himself. He has given an account of the building of that machine, which occupied five years, in his paper of 1905, entitled "Experiments with the Langley Aërodrome." As might have been expected, there were endless delays and mishaps, more particularly in developing the motor, which, after the failure of private parties to furnish what they had contracted to deliver, was finally built in the Smithsonian shops under the design and direction of Mr. C. M. Manly. As finally completed, it was a marvel, being a gasoline motor of 52 brake horse-power, weighing with cooling water, carburetter, battery, etc., somewhat less than five pounds to the horse-power—an achievement which now, five years later, has

scarcely been paralleled by the lightest gasoline motors of European builders. The flying weight of the machine complete, with that of the aëronaut, was 830 pounds, its sustaining surfaces were 1,040 square feet, and it was intended to launch it by impulse from a catapult placed on the deck of a house-boat, precisely in the same manner as the models which had flown so successfully in 1896 and in subsequent years.

Attempts were made to launch this machine, with C. M. Manly on board, on the 7th of October and on the 8th of December, 1903. Both trials were failures in consequence of a trivial defect in the launching gear. In the first attempt "the front guy post caught in its support on the launching car and was not released in time to give free flight;" in the second trial the same accident happened to the rear guy post, and the machine was both times more or less wrecked in the launching. As Langley states, "The machine never had a chance to fly at all, but the failure occurred in the launching ways." There is no doubt in my own mind that the apparatus would have flown if it had been well launched into the air.

We can now realize from Langley's report that entirely erroneous impressions were given by the public press in its accounts of these experiments. The method of construction of this proposed war engine had been kept strictly private, and the newspaper reporters, consumed with curiosity, were not allowed to come near enough to see or to understand what occurred. They represented that the machine itself was an unqualified failure, which never could have flown. Explanations subsequently given were disbelieved, very sharp and unintelligent criticism of the expenditure which had been incurred was made in Congress, and the general public was for a time given the impression that the machine itself was a complete abortion and had not a grain of utility.

Meanwhile the funds allotted by the Board of Ordnance had been exhausted and no additional grants were made. Thus was Langley, with success in sight, finally defeated and deprived of the honor which he craved, of being the first to exhibit dynamic man-flight in the air. He was decried and ridiculed, both in prose and verse, his experiments were misrepresented, and he was called a "professor wandering in his dreams"; so that all his other contributions to science were for a time obscured by a failure due to the trivial defect in his launching gear and by the lack of far-sightedness in our public men.

We all know how all this told upon him. There is no doubt that the disappointment shortened his useful life and brought on the attack of paralysis which ended his days.

His lack of success was probably due to the fact that, like Maxim, Ader, Kress, and many others, he undertook too much at once by endeavoring to produce a full-fledged dynamic flying-machine *ab initio*, before making sure of the control, the stability, and the possibility of alighting safely; but he rescued the problem from contempt, he laid the lines which must be followed, and, having published the results of his experiments and given other men data upon which to conquer the air, he will ever be remembered as the precursor and the pathfinder of successful flying-machines.

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For the years 1887-'88.
Year ending June 30, 1889.
Year ending June 30, 1890.
Year ending June 30, 1891.
Year ending June 30, 1892.
Year ending June 30, 1893.
Year ending June 30, 1894.
Year ending June 30, 1895.
Year ending June 30, 1896.
Year ending June 30, 1897.
Year ending June 30, 1898.
Year ending June 30, 1899.
Year ending June 30, 1900.
Year ending June 30, 1901.
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Year ending June 30, 1903.
Year ending June 30, 1904.
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SMITHSONIAN MISCELLANEOUS COLLECTIONS
PART OF VOL. XLIX

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ON THE

PACIFIC COAST

1897 to 1906

BY

ALEXANDER G. McADIE, M. A.

(No. 1721)

CITY OF WASHINGTON
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ACKNOWLEDGMENTS

This catalogue of earthquakes on the Pacific Coast has been compiled, at the request of the Secretary of the Smithsonian Institution, as a continuation of the catalogue prepared by Prof. Edward S. Holden, formerly director of the Lick Observatory, issued in 1898 in the series of Smithsonian Miscellaneous Collections No. 1087.

The sources of information are:

1. Records of United States Weather Bureau; the notes of regular and coöperative observers, made as nearly as practicable at the time of each earthquake and submitted at the close of each month.

2. Lick Observatory records, kindly furnished by Doctor Wallace Campbell, director of the observatory, including the lists of earthquakes in California in 1886-7-8, compiled by Prof. Charles D. Perrine and published as Bulletin Nos. 155 and 161 of the United States Geological Survey.

3. The records of the Students' Observatory at Berkeley, University of California, under the direction of Prof. A. O. Leuschner; the Chabot Observatory at Oakland, under the direction of Prof. Charles Burckhalter; the personal notes of Prof. A. G. McAdie, at San Francisco.

4. A manuscript list of earthquakes compiled by Prof. Harry Fielding Reid, of Johns Hopkins University, for the United States Geological Survey, the use of which was kindly granted by the Director of the Survey.

5. The records of the observatory at Mare Island, under Prof. T. J. J. See, and the official report upon the earthquake of March 30, 1898, furnished by Admiral H. W. Lyon, U. S. N.

ALEXANDER G. MCADIE.

CATALOGUE OF EARTHQUAKES ON THE PACIFIC COAST 1897 to 1906[1]

By ALEXANDER G. McADIE

1897. **January** 1; Berkeley; 1:10 p. m. Distinct shock; duration, 5 seconds; recorded on duplex seismograph at Students' Observatory.—Prof. A. O. Leuschner.

1897. **January** 16; Mount Hamilton; 3:58:41±5 a. m. Intensity II on R-F. scale.—Prof. W. W. Campbell.

3:58:35±5 a. m. R. F. I. Two rather long, slow waves, lasting one and a half or two seconds; scarcely any trace on duplex seismograph; did not start the Ewing instrument.—Prof. C. D. Perrine.

1897. **January** 17; San Francisco; 1:09:52 p. m. Sharp shock felt in all parts of the city. Two well-defined counter-vibrations of considerable force.—Prof. A. G. McAdie.

Two slight shocks about four seconds apart. Motion vertical.—Prof. George Davidson.

Oakland; Chabot Observatory. Seismograph showed heavy disturbance, vibrations mainly from east to west.—Prof. Charles Burckhalter.

Alameda; 1:11 p. m. Complicated record made on duplex principally east and west. The magnified record is 6 mm. long in this direction and 2 mm. north and south.—Prof. C. D. Perrine.

Oakland; 1:11:11 p. m. Reported by A. H. Babcock two sharp shocks about a second apart; time of second shock given and believed to be correct within a second.

1897. **January** 17; Oakland; 1:10:55±2 p. m. The shock was accompanied by a distinct report.—G. R. Lukens.

Mills College; 1:11 p. m. Shock short, but sharp and distinct. Reported by Josiah Keep. The duplex record shows an area of 7 mm. north and south and 4 mm. east and west, containing a great number of individual vibrations impossible to unravel. There are also one double wave and one or two single ones extending to the west (?) of the main disturbance.—C. D. P.

San Leandro.

[1] The Roman numerals I to X, placed next after the date, represent the intensity on the Rossi-Forel scale.

1897. **January** 20; Oakland. Reported at Chabot Observatory.

San Francisco.

1897. **January** 23; San Leandro.

1897. **January** 26; Newport, Oregon, 2:45 p. m. Sharp; lasted about 3 seconds.

1897. **January** 29; Niles; 3:03 a. m. Observer, Wm. Barry.

1897. **February** 16; Descanso.

1897. **February** 18; Mount Hamilton; 8:3:40 p. m. R.-F. I. and 8:4:30 p. m. R-F. 11. 8:3:52 p. m. doubtful.

1897. **February** 25; Descanso.

1897. **March** 6; Eureka, Cal. Earthquake from 9:28:30 a. m. to 9:29:10 a. m. There were five distinct shocks, increasing in violence to the third shock and then diminishing to the fifth. Slight tremors were felt for nearly two minutes after the first shock. The shocks followed each other at intervals of from five to ten seconds. The third shock rattled the doors and windows and swayed the building considerably. The movements were from the southwest to northeast. No gyratory movement perceptible. It was very dark along the whole line seaward, as if smoke had been belched up from the sea depths, covering fully fifteen degrees of the sky. Little or no wind at the time; barometer 29:55, temperature 40°.—A. H. Bell, Observer, Weather Bureau.

1897. **March** 15; Ukiah; 11 p. m. Vibrations north to south and lasted about ten seconds.

Highland Springs, near Lakeport, 10:51 p. m. Heavy shock, lasting 10 seconds.—W. B. Collier.

1897. **May** 14; Reno, Nevada; about 6 p. m., lasting several seconds; direction from north to south.

1897. **May** 15; Crescent City, Edmanton.

1897. **May** 15; San Diego; about 4 a. m. Light.

1897. **May** 15; Carson City, Nevada. Severe shock at 11:04 a. m., lasting 2 seconds. Seismograph showed vibration from northeast to southwest. Plaster broken in many buildings.

1897. **May** 22; San Diego; 6:58 a. m. Sharp, lasting 2 seconds.

1897. **May** 23; Crescent City.

1897. **May** 29; Crescent City.

1897. June 20; San Francisco; 12:14:40 p. m. Lasted 20 seconds; severe shock.—Prof. A. G. McAdie.

F. W. Edmonds, of U. S. Coast and Geodetic Survey, says there was a slight shock at 6:37 a. m. There was a tremor at 12:59 p. m. This shock stopped many clocks in San Francisco. Most of these stopped at 12:13 p. m. This disturbance was felt at Oakland, Berkeley, Campbell, Centerville, Hollister, Milton, Rio Vista, Sacramento, San José, San Leandro, Santa Cruz, Stockton, Napa, Niles, Mount Hamilton, College Park, Mills College, Gilroy, Salinas, Los Gatos, Templeton, Monterey, Pacific Grove, Modesto, Newman, Cantau Creek, Merced, Visalia, Santa Rosa, Haywards, Decoto, Watsonville, Hanford, Fresno, Gonzales, Redwood City, San Rafael.

Lick Observatory; 12:12:55 to 13:5 p. m. Direction, northeast and southwest; heavy; rocked pictures on the wall. Prof. W. W. Campbell. Both Ewing and duplex seismographs recorded the shock. record of duplex not complete; pen obstructed. The record is 16 mm. in length and north and south direction and 9 mm. east and west. The Ewing instrument gave all three components; duration slightly over 30 seconds; waves of considerable amplitude and slow, the greatest motion being east and west. The heaviest wave seems to have occurred one second after the commencement of the shock, the amplitude magnified being 16.3 mm., or an earth motion of 4.1 mm. east and west. There is also a north and south component of this wave of 6.3 mm. magnified, corresponding to an earth movement of 1.5 mm. Hence the greatest double amplitude of this wave is 4.4 mm. with a period of 1.5 seconds, which gives an intensity of 39 mm. per one second, or 11 on the Rossi-Forel scale. The next move recorded by the east and west pen is probably the one of greatest intensity, although of small magnitude; amplitude, 0.25 mm.; time, 0.37 second, from which intensity would be IV on the R.-F. scale. The greatest vertical disturbance occurred about the middle of the shock, when the record showed four waves of 4 mm. double amplitude magnified with an average period of about 2 seconds. The whole shock exhibits marked irregularities; none of the waves are smooth, but all have lesser vibrations superposed upon the larger.

College Park. The seismograph at the University of the Pacific registered the shock. The tracing is very complicated and is three times the size of the tracing by a similar instrument at the Lick. The axis of greatest disturbance is northwest and southeast, the record measuring 50 mm. in this direction. At right angles to this the record measured 28 mm. Allowing for a magnification of 4.0 diameters, this makes the greatest actual motion of the earth about 12 mm.

Mills College, 12:13 p. m. Severe, set chairs to rocking; double, the latter part being heavier. Total length of tracing northeast and southwest is 30 mm. and at right angles to this 18 mm. A compact mass of vibrations covering 8 mm. in diameter, from

which there extends on all sides several larger excursions of the pen.—Josiah Keep.

Cantau Creek, Fresno County. At 12:13 p. m. S. C. Lillis felt shock, duration about 15 seconds, ninth shock; undulation and whirling motion.

San José. Almost every clock in town stopped.

Gilroy. Much damage done to brick buildings; chimneys all over town cracked or demolished and plastering fell to floor. Sargents reports destruction of adobe building.

Hollister. Scarcely a brick building in town that has not suffered. Top of north fire wall of McMahon House fell upon adjoining buildings. Much window glass broken.

Salinas. Much damage done. Firewalls tumbled into street; chimneys down and plate glass cracked.

Monterey. Portion of adobe wall of San Carlos Mission Church fell, frightening worshipers, and several fainted.

Gonzales. Heaviest earthquake ever felt in this locality occurred today. The vibrations were from north to south and lasted a full quarter of a minute.

Fresno. Duration variously estimated at from 3 to 10 seconds. Hughes Block and Temple Bar buildings shaken. No damage reported, but a general feeling of alarm. At the residence of T. C. White a vase was broken.

Redwood City. Shock rang the bell in the dome of the new High School building and cracked the plaster in some of the old buildings.

Oakland; 12:13:35 p. m. The big clocks of the city were stopped at thirteen minutes after the hour of noon today by as violent an earthquake as ever visited Oakland. The shock probably lasted seven seconds, although it seemed much longer. It was followed by another decided tremor, which, however, was not comparable with the first. The excitement for a time was great. People ran out of their houses and into the middle of the street. In all the big churches of the city the congregations were attentively listening to sermons, and the shock abruptly ended several of these services. As far as can be learned, there were no windows broken or other actual damage done, although many are complaining that valuable china and glass ware were knocked from tables and shelves and ruined. The seismograph at the Chabot Observatory shows that there were three distinct tremors. The direction of the first was from northwest to southeast, while the others were from northeast to southwest. The successive tremors lasted a trifle over eight seconds and the time recorded at the observatory is 12h. 13m. 35s. The quake was distinctly felt in Berkeley, Alameda, and other towns in the vicinity.

1897. **June** 21; Gilroy. Light shock at 5:15 a. m.

Salinas. Light shock just after midnight.

1897. **June** 24; Santa Barbara. Light shock at 6:10 a. m.

1897. **July** 14; Niles. Light shock at 10:19 p. m.

1897. **July** 18; Castle Pinckney.

1897. **July** 19; Santa Barbara. Two strong shocks at 11:45 p. m. The first shock lasted about 4 seconds; second shock much stronger, but of shorter duration; caused the old tower-clock bell to strike.

1897. **July** 26; San Francisco; 5:40:35 p. m. Moderate shock; lasting about 2 seconds; quick, jerky motion.—Prof. A. G. McAdie.

Mount Hamilton; 5:40:50 p. m. The duplex seismograph shows a small mark, which, however, more resembles creeping of pen than an earthquake.—Prof. E. S. Holden.

Alameda. Mr. Perrine's seismograph gives a record of the shock, which, however, was very light—only one or two irregular, short waves.

Berkeley; 5:42 p. m. Vibrations east and west.

Oakland. Very light. At Chabot Observatory the instruments showed only a slight mark on the plate. Duration, about 3 seconds.

1897. **August** 19; Ukiah.

1897. **September** 2; Hollister.

1897. **September** 6; Descanso.

1897. **September** 17; Eureka. Quite a severe shock at 9:10 p. m., lasting over 40 seconds. Motion south to north and very steady. No gyratory movement noticed. Barometer 30:03, temperature 74°, wind light.—A. H. Bell, Observer.

1897. **September** 22; Descano.

1897. **September** 27; Olympia, Washington. Light shock at 1:30 a. m.

1897. **October** 2; Campbell, Niles.

Niles; 8:41 a. m.—Wm. Barry.

College Park; 8:41:57 a. m. Shock quite marked, especially on upper floors of building.—Prof. H. D. Curtis.

San Francisco; 8:42 a. m.; intensity II, R.-F. scale.—Mr. W. M. Pierson.

Santa Cruz; 8:45 a. m.; also at Alma.

1897. **October** 5; Stockton; 7:44 p. m.

1897. **October** 17; Campbell; San José, 3:30 p. m.

Niles; 3:30 p. m. Heavy shock.—Wm. Barry.

Lick Observatory; 3:30:26 31 p. m. Record on duplex, entirely southeast and northwest.

San Francisco; 3:30:30 p. m.—A. G. McAdie.

1897. **October** 27; Descanso.

1897. **October** 28; Eureka. Slight earthquake shock reported as having occurred at 5:30 p. m. Barometer 30:06, temperature 62.

1897. **November** 8; Lick Observatory; 3:30:8 p. m.

1897. **November** 12; Descanso.

1897. **November** 21; Randsburg; 11:30 a. m. and 12:30 p. m.

1897. **November** 22; Descanso, Escondido, Fallbrook.

1897. **November** 25; Eureka. Slight shock of earthquake from 5:20 to 5:20:07 (?). Movement all lateral, west to east, in three successive jolts. Windows and doors rattled slightly. Barometer about 30:25, temperature 38.

1897. **November** 27; Eureka. Slight shock at 7:8 to 7:8:5 a. m. Buildings swayed considerably and windows and doors rattled loudly.

1897. **December** 6; Forest Grove, Oregon; 8:30 p. m. Slight.

1897. **December** 10; Lick Observatory. Slight shock felt by several persons after midnight. Barely a trace on the duplex. Ewing instrument not started.

1897. **December** 15; Waterville, Washington. Duration, 4 to 6 seconds; direction, northwest to southeast.

Lakeside, Washington. Severe.

1897. **December** 16, 17, and 20; Lakeside, Washington. All light.

1897. **December** 23; San Francisco; 5:20 a. m. Double tremors.—Prof. A. G. McAdie.

Mills College; 5:15 a. m. Distinct shock.—Josiah Keep.

1897. **December** 26; Niles; 7:06 a. m. Direction, north and south; duration, 5 seconds.—Wm. Barry.

1898.—**January** 1; Peachland.

Santa Rosa. Two distinct shocks shortly after 5 a. m.; west to east; duration, 25 seconds.

1898. **January** 29; Eureka. Light earthquake was felt at 4:04 a. m. and lasted about 8 seconds. Doors and windows rattled. Barometer 30:32, temperature 38.

1898.—**February** 6; Bishop.

1898. **February** 7; Lick Observatory; 0:38:03 a. m. A single tremor; then, after 2 seconds, two rather long waves, north and south, lasting 1½ to 2 seconds. R.-F. I and II.—Prof. C. D. Perrine.

1898. **February** 15; Bishop (five distinct shocks).

1898. **March** 2; 1:52 p. m. The shock was light and did no perceptible damage.—J. P. Bolton, U. S. Weather Bureau.

1898. **March** 3; Descanso.

1898. **March** 7; Pacific Ocean midway between Mazatlan and Hawaiian Islands. Barkentine "Portland," Capt. Larsen, reported four shocks; first at 10:12 p. m., G. M. T., very severe and lasted 20 seconds; milder shock 30 minutes later, and two more during afternoon. Weather nearly calm.

1898. **March** 17; Upper Lake.

Highland Spring, at midnight; west to east.

1898. **March** 30; Lick Observatory; 11:42:22 p. m.; duration, 40 seconds. A heavy shock. Good record on duplex instrument.

San Francisco; 11:42:38 p. m. One of the severest earthquakes experienced in San Francisco; intensity VII on the R.-F. scale; chimneys twisted, chandeliers broken, and considerable damage done in the city; duration, about 40 seconds; vibrations southwest to northeast and violent gyratory motion.—A. G. McAdie.

Alameda, College Park, Carson, Nevada (11:45 p. m.), Agnews, Campbell, Fort Ross, Antioch, Auburn, Benicia, Bolinas, Colusa, Lodi, Martinez, Monterey, Pacific Grove, Del Monte, Port Costa, Petaluma, Sonoma, San José, Georgetown, Hollister, Iowa Hill, Lytton Springs, Niles, North San Juan, Oakland, Oleta, Peachland, Santa Rosa, Rio Vista, Sacramento, San Leandro, Santa Cruz, Stockton, Upper Lake, Vacaville, Vallejo, and West Point.

Napa; 11:44 p. m. Heavy. W. H. Martin.

Chabot Observatory, Oakland. Professor Burckhalter gives the time as 11:42 p. m. Intensity V on R.-F. scale. Stopped mean time clock.

Berkeley; 11:42:26 p. m.; duration, 14 seconds; direction, east to west and north to south and also vertical.

This earthquake wrought such damage at Mare Island Navy Yard that it may properly be known as the Mare Island earth-

quake. Fortunately the loss of life was small, owing to the hour. Had the shops been crowded there probably would have been many fatalities.

Admiral H. W. Lyon, U. S. N., has furnished the following information:

"On the night of March 30, 1898, at 11:40 p. m., there was an earthquake at this yard which lasted forty seconds. The violence of the shock was greater than any shock previously experienced on this island, as far as can be learned from the oldest inhabitants.

"A detailed account of the damages done is set forth in a report to the commandant, dated April 5, 1898.

"Upon the recommendation of the Secretary of the Navy, both Houses of Congress being at that time in session, very promptly made an appropriation of $350,000 to repair and reconstruct buildings and property damaged by the earthquake."—From annual report of Civil Engineer R. C. Hollyday, U. S. N., dated August 1, 1898.

In addition to the appropriation of $350,000 made by Congress, a separate appropriation was made for a new hospital of about $95,000.

1898. April 7; Napa; 12:30 a. m.—W. H. Martin.

1898.—April 12; College Park; 4 p. m.

1898. April 14; San Francisco; 10:53 p. m. and 11:7 p. m. Short, gentle, shocks.—A. G. McAdie.

Oakland, Chabot Observatory; 11:9:13 p. m. Intensity V on R.-F.—Prof. C. Burckhalter.

Napa. Two shocks at 10:45 and 11:10 p. m.—W. H. Martin.

Eureka; 10:50 and 11:10 p. m. Latter shock heavier. Big city clock stopped.

Mendocino. Much damage to property; many chimneys thrown down and cracked; many monuments in Evergreen Cemetery thrown, twisted on bases.

Little River. On stage road from Mendocino to Ukiah many trees down.

Point Arena. Much damage. Lighthouse tower cracked for several feet and lights extinguished.

Greenwood. Four houses wrecked and portion of wharf destroyed. Stages for interior compelled to return, as roads were impassable. Vessels in harbor felt grinding motion. In lumber yards, stacks blown down.

Ukiah. There were 22 distinct shocks in this city.

Fort Bragg; 11:05 with vibrations from south to north, and again at 11:22 heavier shock, which continued for 15 seconds, vibrations from west to east.

Mills College; 11:5 p. m.

Alameda. Mr. Perrine's seismograph gives a record of an extensive shock. Waves clearly marked into east and west, north and south, and southeast and northwest.

College Park; 11:10:39 p. m.

Berkeley. Ewing seismograph records only one shock although two were felt by many persons. "The disturbance commenced with minute vibrations in all three components, which gradually increased in the north-south and the east-west components, reaching a first maximum in the east-west direction at thirty-seven seconds (reckoned from the beginning), and a second and principal one at seventy-two seconds. The principal disturbance in the north-south direction commenced at about thirty-two seconds and lasted to the fiftieth second. During this interval the intensest vibration occurred at forty-nine seconds, almost exactly from south to north. . . ." "By treating the displacement as belonging to a simple harmonic motion, the actual velocity of the ground at forty-nine seconds is found to be 0.47 inch (12 mm.) per second, and its actual acceleration 1.29 inches (33 mm.) per second. . . . The velocity of the greatest westerly displacement is 0.13 inches (3 mm.) and acceleration 0.32 in. The greatest displacements were north-south 0.34 inch; east-west 0.10 inch."—Prof. A. O. Leuschner.

1898. **April** 16; Crescent City; 5:40 a. m. R.-F. III or IV.

1898. **April** 18; Prairie Camp (Mendocino County). Nine severe shocks. Possibly the shocks of April 14.

1898. **April** 21; Descanso.

1898. **April** 25; Albion, Mendocino. Severe shock.

1898. **April** 26; College Park; 10:30 p. m. Recorded on seismograph and also felt. (Explosion of Santa Cruz powder works (?).—C. D. P.)

1898. **April** 30; Claremont, Pomona.

1898. **May** 2; College Park; 6:2 a. m.—H. D. Curtis.

Salinas. Two distinct shocks at 6:5 a. m.

Santa Cruz.

1898. **May** 9; Gilroy, about 7 a. m. Light.

1898. **May** 17; Cedarville.

1898. **May** 19; Cedarville.

1898. **May** 20; Lick Observatory. Light shock; 6:48:53 a. m.

College Park; 6:49 a. m.—H. D. Curtis.

1898. **May 22**; College Park; 11:15 a. m. Left a mark one-eighth inch on seismograph.—H. D. Curtis.

1898. **May 28**; Hollister.

1898. **May 29**; Santa Barbara; 7:3 p. m. Light.

1898. **May —**; Fort Bragg. Frequent shocks.

1898. **June 3**; Los Olivos; 10:20 p. m. Felt throughout the Santa Ynez Valley.

Santa Barbara; 10:18 p. m. Heaviest for some years. Vibration from east to west.

1898. **June 8**; Ukiah.

Point Arena; 11:30 a. m. Two severe ones. Another at 1 p. m.

1898. **June 9**; Ukiah, Upper Lake.

1898. **June 11**; Ukiah.

1898. **June 23**; Descanso.

1898. **June 24**; Descanso.

1898. **June 30**; Los Angeles; 11:26 p. m. Sharp.

1898. **August 7**; Oakland, Chabot Observatory. Charles Burckhalter, observer. 2:6:00 p. m. Duration, 5 seconds; direction of vibration, southwest to northeast; intensity III on R.-F. scale.

San Francisco; 11:57 a. m.—A. G. McAdie.

Berkeley; 11:58 a. m. Direction, northwest. Light shock.

1898. **August 12**; Alameda. Several vibrations, covering an area of 9 mm. east and west by 4 mm. north and south.—C. D. P.

Mills College; 6:10 a. m.—Josiah Keep.

1898. **August 19**; Albion; 2:30 p. m.—R. B. Funk.

1898. **August 28**; San Leandro.

Berkeley (?). Very light shock, southeast to northwest.

1898. **August 31**; San Leandro.

1898. **September 9**; Eureka. Quite a severe shock of earthquake occurred at 12:53 p. m., lasting about 5 seconds; the movement was from southeast to northwest; the building in which office is located shook considerably.

1898. **October** 13; Bishop.

1898.—**October** 15; Ukiah.

1898. **October** 19; Eureka. Light shock of earthquake occurred at 11:35 p. m. Barometer about 29:98, temperature about 46.

1898. **October** 23; San Bernardino.

1898. **October** 25; Oakland, Chabot Observatory. Prof. Chas. Burckhalter; 3:15:17 p. m.; duration, 5 seconds; direction of vibration, southwest to northeast; intensity, II on R.-F. scale. Very feeble shock, direction circular.

1898. **October** 27; Lick Observatory; 2:22:24 p. m. Northeast and southwest. R.-F. II. Duplex shows a single nearly straight line.

1898. **November** 5; Summerdale.

Lick Observatory; 9:9:8 p. m.

1898. **November** 14; Niles; 1:10 p. m.; second shock, 1:57 p. m. Observer, Wm. Barry.

1898. **November** 19; Lick Observatory; 11:27:1. Three close vertical shocks; last two very light, first one fairly strong.—Prof. W. W. Campbell.

1898. **November** 25; Eureka. Light shock of earthquake occurred at 9:22 p. m. Barometer about 30:18, temperature about 35°.

1898. **December** 7; San Leandro.

Niles; 7:29 p. m. Observer, Wm. Barry.

Alameda; 7:38:47 p. m. R.-F. III or IV. Direction, east and west; duration, 4 seconds. A grinding noise preceded the heaviest shock. Seismograph (duplex) shows jagged irregular mark 3½ mm. northwest and southeast by 1½ mm. at right angles.—Prof. C. D. Perrine.

1899. **January** 2; Guerneville; 5 a. m.

1899. **January** 6; Berkeley; 2:41:28 a. m. (?).

1899. **January** 9; Berkeley. Ewing seismograph records slight southwest motion; duplex seismograph shows slight southeast motion.

1899. **January** 10; Berkeley. Ewing records southwest motion; duplex records northeast.

1899. **January** 11; Berkeley. Ewing records southwest motion.

1899. **January** 12; Lick Observatory; 11:40:29 p. m. Intensity II.

1899. **January** 13; Suisun, Sonoma.

Napa; 1:20 p. m. Sharp.—W. H. Martin.

1899. **January** 24; San Bernardino.

1899. **February** 3; Lick Observatory; 9:8:57 (?).

1899. **February** 10; Napa-Calistoga. Sharp shock reported at Calistoga at 10:10 a. m.—W. H. Martin.

1899. **February** 18; Crescent City; 4:40 a. m.

1899. **March** 7; Ukiah.

1899. **March** 30; Point Arena; 9:50 a. m. Intensity IV.

1899. **April** 4; Berkeley; 5:46:20 a. m. Felt at 2023 Bancroft Way by S. D. T. 5:46:22 a. m. noted by H. K. P.

Alameda.

Mills College.

1899. **April** 5; Oakland, Chabot Observatory. Direction circular; intensity II on the R.-F. scale.

1899. **April** 14; Cuyamaca.

1899. **April** 16; Eureka. One of the severest shocks of earthquake ever experienced here occurred at 2:41 a. m. The vibrations were from south to north and lasted about 15 seconds. Although the shock was violent and long-continued, the only report of damage came from Dolbeer and Carson's lumber mill, where the shock loosened the iron flue connecting boilers and smokestack, and in consequence the mill was closed pending repairs. Barometer about 30:11 inches, temperature about 46°.

1899. **April** 16; Hydesville.

1899. **April** 18; Hydesville.

Eureka. Light shock of earthquake was felt at 4:53 a. m. The vibrations were from east to west, and lasted about 5 seconds. Barometer about 30:05, temperature about 46°.

1899. **April** 24; Fort Bragg; 10:10 p. m. and again at 10:20 p. m.

1899. **April** 30; Berkeley; 2:41:30 p. m. Duration, 14 seconds; principal motion west; slight motion to north. R.-F. II. First shocks 2 seconds; first half second 3 distinct vibrations; total displacement,

1/25 inch. Felt also at Alvarado, Campbell, Capitola, Coyote, Gilroy, Glenwood, Hollister, Los Gatos, Monterey, San José, Oakland, Pacific Grove, Salinas, San Leandro, Santa Cruz, Soledad, Stanford University, Stockton, Modesto.

Oakland, Chabot Observatory; 2:41:29 p. m. Observer, Prof. Burckhalter; duration, 10 seconds; direction, southeast to northwest; intensity III.

Niles; 2:41 p. m. Observer, Wm. Barry.

Lick Observatory; 2:41:15 to 2:41:39 p. m.—Dr. C. D. Perrine. Time, 2:41:21-24.—Dr. W. W. Campbell. "A long-continued shock; waves long and rather even; heaviest disturbance after the first 10 or 12 seconds." Intensity R.-F. III or IV.
San Francisco; 2:41:35 p. m.—A. G. McAdie.

1899. May 2; Vallejo; 5:37:35 p. m. Intensity I.

1899. May 3; Vallejo; 5:24:54 (?). Intensity I.

1899. May 10; Mare Island; 5:21:48 p. m. Intensity III.

1899. May 13; Bishop.

1899. May 15; Lick Observatory; 6:54:20 p. m. Intensity I.

1899. June 1; 11:20 p. m. Campbell, Capitola, Livermore, Mills College, Morena Dam, Napa, Peachland, Stanford University.

Oakland, Chabot Observatory; 11:19:26 p. m. Observer, Prof. Burckhalter; duration, 8 seconds; direction, southwest to northeast; intensity IV. Stopped mean time clock 11:19:26 p. m. and the Ferry clock at San Francisco 11:19:14 p. m.

San Francisco; 11:19 p. m. Stopped three clocks in Weather Bureau Office.—A. G. McAdie.

Niles; 11:18 p. m. Two sharp shocks. Observer, Wm. Barry.

Napa; 11:18 p. m.—W. H. Martin.

Berkeley; 11:19:07 p. m. Direction, north to south.

1899. June 3; Oakland.

1899. June 5; Bradley.

1899. June 11; Keeler, Milo, Porterville.

Mare Island; 12:56:31 p. m., 12:56:38 p. m., 12:56:52 and 12:56:56 p. m.

1899. June 13; College Park, Vallejo, San José, Napa.

San Francisco; 5:39:31 a. m.—A. G. McAdie.

Berkeley; 5:39:40 a. m. Light shock, with westerly direction predominating. Total displacement less than 1.5 inch.—Prof. A. O. Leuschner.

1899. **June** 19; Mare Island; 12:13:25 p. m. One jolt.

1899. **June** 21; Berkeley; 2:52:17 a. m.

1899. **June** 21; Mare Island; 6:46 a. m. Intensity III.

1899. **June** 25; San Miguel.

1899. **July** 6; Boulder Creek, Campbell, Capitola, Coyote, Elmwood, Gilroy, Glenwood, Gonzales, Hollister, Lathrop, Le Grande, Los Gatos, Merced, Milbrae, Modesto, Mount Eden, Napa, Niles, Oakland, Pacific Grove, Salinas, San José, Santa Cruz, Stockton.

Oakland; Chabot Observatory; 0:09:35 p. m. Observer, Prof. Burckhalter; duration, 20 seconds; direction, northeast to southwest; intensity III.

San Francisco; 12:09:40 to 12:10:11 p. m.—A. G. McAdie.

Niles; 12:08 p. m. Observer, Wm. Barry.

Napa; 12:10 p. m.—W. H. Martin.

Lick Observatory. Moderately strong shock; 12:09:29 p. m. Good record on both instruments.

San Luis Obispo.

Berkeley; 7:09:57 p. m.

1899. **July** 22; San Diego; 0:31:30 p. m. Intensity III R.-F.; vibrations east to west. Stopped the office clock at the Weather Bureau.—F. A. Carpenter, U. S. Weather Bureau.

Los Angeles. Quite a heavy shock at 0:37:22 p. m.—A. B. Wollaber.

1899. **August** 4; Berkeley; 12:44:29 p. m. Direction south to east (?).

1899. **August** 4; Lick Observatory. Very light shock. Prof. Tucker was the only one on the summit who noticed it. His time is 12:44 p. m. A telephone message from Saratoga reports it quite severe there. Neither seismograph showed the least record.—R. T. C.

San Francisco; 12:45:30 p. m. Three or four waves.—A. G. McAdie.

Napa; 12:45 p. m.—W. H. Martin.

1899. **August** 4; Ben Lomond, Boulder Creek, Campbell, Capitola, Glenwood, Lathrop, Los Gatos, Napa, Oakland, San José, Santa Cruz, Tequisquita.

Oakland; Chabot Observatory; 0:44:10 p. m. Observer, Prof. Burckhalter; duration, 6 seconds and 2 seconds; direction uncertain; in-

tensity III. Double shock; first lasted 6 seconds, an interval of 4 seconds, then the shock of 2 seconds.

Niles; 12:45 p. m. Observer, Wm. Barry.

1899. **August** 5; Ben Lomond, Boulder Creek, Campbell, Capitola, Glenwood, Lathrop, Los Gatos, Napa, Niles, Oakland, San José, Santa Cruz, Tequisquita.

Niles; 9:42 p. m. Observer, Wm. Barry.

Lick Observatory; 9:42 p. m. Noticed by Mrs. Keeler and Mrs. Painter.

San Francisco; 9:41:30 p. m.—A. G. McAdie.

Berkeley; 9:41:30 p. m.

1899. **August** 21; San Diego.

1899. **September** 13; Berkeley. Slight shock recorded on duplex.

1899. **September** 16; San Miguel, San Luis Obispo.

Lick Observatory, about 7 a. m. Attachment on duplex Ewing instrument did not go off. The shock was felt by Paul Soto; time, about a quarter past 7.

1899. **September** 20; Needles.

1899. **October** 11; Moreno Dam.

Lick Observatory; 8:57:42 to 47 (?). Intensity III.

1899. **October** 12; Cuyamaca, Peachland, Santa Rosa.

1899. **October** 14; Berkeley; 10:23:05 p. m.

1899. **October** 28; Moreno Dam.

1899. **November** 9; Lick Observatory.

1899. **November** 16; Napa; 7:10 p. m.—W. H. Martin.

1899. **November** 22; Berkeley; 1:17:06 p. m. Direction, east to west.

1899. **December** 12; Chico.

1899. **December** 13; Chico.

1899. **December** 19; Chico.

1899. **December** 20; Chico.

1899. **December** 25; Arcadia, Banning, Claremont, Crafton, Cuyamaca, Duarte, El Cajon, Elsinore, Escondido, Fall Brook, Follows Camp, Girard, Hemet, Indio, La Mesa, Long Beach, Monte, Moreno Dam, Napa, Needles, North Ontario, Norwalk, Ontario, Palm Springs, Pomona, Ravenna, Riverside, San Bernardino, San Dimas, San Jacinto, Sierra Madre, Tehachapi, Tustin, Whittier, Redlands.

San Diego; 4:25:19 a. m. Intensity IV R.-F. Most severe shock for years.—F. A. Carpenter, U. S. Weather Bureau.

Los Angeles. Severe shock at 4:25:20 a. m. Three shocks at intervals of about half a minute.—Observer, U. S. Weather Bureau.

1900. **January** 1; San Jacinto.

1900. **January** 2; San Jacinto.

1900. **January** 4; San Jacinto.

1900. **January** 5; Napa.

1900. **January** 6; Los Gatos.

1900. **January** 9; San Jacinto.

1900. **January** 13; San Jacinto.

1900. **January** 14; Campbell, Niles, San Leandro.

Niles 11:27 a. m.—Wm. Barry.

Napa; 11:30 a. m.—W. H. Martin.

Lick Observatory; 11:26:14 a. m. Sharp shock record on duplex. Ewing started, but did not run properly.

1900. **January** 15; San Jacinto.

1900. **January** 21; Eureka. Light earthquake occurred at 4:11 a. m., lasting about 20 seconds. The vibrations seemed to be from southeast to northwest. Barometer about 30:08, temperature about 44.

1900. **January** 27; San Jacinto.

1900. **January** 28; Moreno Dam.

1900. **January** 31; Peachland.

1900. **January** —; Palm Springs (frequently during first part of month).

1900. **February** 2; Claremont.

1900. **February** 7; San Jacinto.

1900. **February** 8; Berkeley; 4:40 a. m. Light shock.

1900. **February** 9; Petaluma; 4:30 a. m. Intensity VI.

San Jacinto.

1900. **February** 13; Cuyamaca.

1900. **February** 28; Winnemucca, Nevada. Heavy earthquake shock felt at 1:30 p. m. Vibrations west to east for about 8 seconds. Although the shock was severe enough to give a good shaking, no damage resulted.—W. J. Olds, U. S. Weather Bureau.

1900. **March** 18; San Jacinto.

1900. **March** 12; Mills College; 6:45 a. m. Intensity I or II.

1900. **March** 20; Peachland.

1900. **March** 21; Claremont.

1900. **March** 26; Napa, Vacaville, Vallejo.

Napa; 6:50 a. m.—W. H. Martin.

1900. **March** 31; Lick Observatory; 1:51:40 p. m. Intensity III.

1900. **April** 5; 5:47 a. m.

1900. **April** 9; Fallbrook.

1900. **April** 14; Eureka. Light earthquake shock occurred at 6:41 a. m.; duration about 8 seconds; vibrations from east to west. Barometer about 30:16, temperature about 49.

1900. **April** 15; San Jacinto.

1900. **April** 16; San Jacinto.

Napa; two shocks at 1:45 p. m.—W. H. Martin.

1900. **April** 23; Cuyamaca.

1900. **April** 30; Lick Observatory; 2:41:14-39 p. m. Intensity III or IV. Berkeley, Decoto, San Carlos, Oakland, San José, Stockton, San Francisco, Alameda, San Quentin, Salinas, Monterey, Modesto, Los Gatos, Pacific Grove.

1900. **May** 10; San Jacinto.

1900. **May** 20; Mount Eden.

Niles; 5:05 a. m. Heavy.—Wm. Barry.

1900. **June 9**; San Ardo.

1900. **June 13**; San Francisco; 5:39:5 a. m. Intensity II.

Berkeley, Mare Island, College Park.

1900. **June 17**; Mare Island; 12:56:31½ and 12:56:55½ (?).

1900. **June 19**; Cuyamaca.

Mare Island; 12:13:25 p. m. Intensity I.

1900. **June 20**; Cuyamaca.

1900. **June 21**; Mare Island; 6:45:52 a. m.

1900. **June 26**; Keeler.

1900. **July 10**; Lick Observatory. Light short shock felt by Prof. Tucker and Dr. Crawford; no record on either seismograph; time, about 7:30 a. m.

1900. **July 12**; Branscomb.

1900. **July 13**; Branscomb.

1900. **July 23**; San Diego; 6:40 a. m.

1900. **July 28**; San José.

Lick Observatory; 0:20:56 p. m.; duration, 4 seconds; intensity R.-F. II. Slight record on duplex.

1900. **July 29**; Mills College; 5:7 a. m.

San Francisco; 7:25 (?). Intensity II or III.

1900. **August 16**; Ferndale.

Eureka. Very light earthquake occurred at 8:58 a. m., lasting a few seconds; the vibrations were from south to north. Barometer about 30:07, temperature about 58°.

1900. **August 18**; Elsinore.

1900. **August 19**; San Jacinto.

1900. **August 31**; Mills College, Niles, San José, Stanford University, Tequisquita.

Oakland, Chabot Observatory. Observer, E. W. 7:21:10 p. m. Intensity II.

Niles; 7:21 p. m.—Wm. Barry.

Berkeley; 7:21 p. m.

Lick Observatory; 7:21:1 p. m.

1900. **September** 10; Berkeley; 1:57:32 p. m.

1900. **September** 12; Berkeley; 8:13:31 p. m. Light shock.

1900. **September** 19; Oakland, Chabot Observatory. Midnight; intensity II.

Berkeley; 11:54 p. m.

1900. **September** 28; Gilroy; 4:17 a. m. Intensity V.

1900. **September** 28; Tequisquita Rancho.

1900. **October** 1; Eureka. Light earthquake shock occurred at 6:15 a. m.; vibrations from east to west. Barometer about 29:87, temperature about 55°.

1900. **October** 18; San Luis Obispo.

1900. **October** 24; Tequisquita Rancho.

1900. **November** 5; Cuyamaca.

1900. **November** 8; Branscomb.

Westport; 8:15 to 8:50 (?). Two shocks.

1900. **November** 13; Penn Grove; 9:59 a. m. Intensity IV.

1900. **November** 14; Fall Brook.

1900. **November** 19; Cuyamaca, Moreno Dam.

1900. **November** 24; Oakland, Chabot Observatory. Observer, Prof. Burckhalter. 2:20:12 a. m.; duration, 8 seconds; direction, southwest to northeast; intensity II.

1900. **November** 25; Napa; 12:45 a. m.—W. H. Martin.

Berkeley; 12:39 a. m. Light shock.

1900. **December** 5; Lick Observatory; 10:24:14 a. m. Intensity I.

1900. **December** 30; San José.

Lick Observatory; 8:06:0 p. m. Timed by several. Slight mark on duplex. Plate of Ewing started, but not the clock.

1901. **January** 11; Ukiah.

1901. **January** 21; Berkeley, Mills College, Niles, Oakland, San Francisco.

Niles 11:00 p. m.—Wm. Barry.

1901. **January** 23; Ukiah.

1901. **January** 25; Tequisquita Rancho.

1901. **January** 28; Tequisquita Rancho.

1901. **February** 5; Berkeley; 5:42:12 p. m.

1901. **February** 13; Berkeley; 4:42:35 a. m. Severe enough to rattle windows and furniture.

1901. **February** 13; Kentfield, Mills College, Napa, Oakland.

Oakland, Chabot Observatory. Observer, Prof. Burckhalter. 4:42:10 a. m.; duration, 8 seconds; direction, northeast to southwest; intensity II.

Napa; 4:42 a. m.—W. H. Martin.

San Francisco; 4:43:12 a. m.—A. G. McAdie.

1901. **February** 18; San Francisco; 6:30 a. m.—A. G. McAdie.

1901. **March** 2; Hollister, Huron, Paso Robles, Porterville, San Ardo, San Miguel, Santa Maria, Summerdale, Visalia.

Lick Observatory. Good record duplex and Ewing, but coördinates not worked up.

San Francisco; 9:37:30 p. m.—A. G. McAdie.

1901. **March** 3; San Francisco, San Luis Obispo.

1901. **March** 4; Porterville, San Francisco.

1901. **March** 5; Paso Robles, Porterville.

1901. **March** 6; San Ardo, San Luis Obispo.

1901. **April** 13; Tequisquita Rancho.

1901. **April** 14; Palomar Mountain.

1901. **April** 19; Alameda. Intensity III (?).

1901. **May** 22; Cuyamaca, Escondido, Palomar Mountain, San Jacinto.

1901. **June** 3; San Luis Obispo.—John R. Williams, U. S. Weather Bureau.

1901. **June** 26; Point Lobos, San Francisco.

Berkeley; 2:41:16 p. m. Direction northwest to southeast; light; and again, at 4:55:45 p. m., light northwest to southeast.

1901. **July** 30; San Luis Obispo; 11 a. m.—J. R. Williams.

1901. **August** 7; Boulder Creek, Los Gatos, Mills College, San José, Santa Cruz, Tequisquita Rancho.

Niles; 2:23 a. m.—Wm. Barry.

Lick Observatory. Intensity I or II.

1901. **August** 10; Hollister.

1901. **August** 14; Cayucos, Hollister, Santa Cruz, 3:11 a. m.

San Luis Obispo, Salinas.

1901. **August** 17; San Francisco; 8:37:34 (?).—A. G. McAdie.

1901. **August** 18; San Leandro.

1901. **September** 2; Berkeley. Time not given. Light shock on duplex northwest to southeast, then toward west to northwest.

1901. **September** 3; Berkeley; 7:01 (?). Direction northeast to southwest; light shock, lasting a few seconds.

1901. **September** 3; Salinas.

Berkeley. Light shock on duplex toward southeast by east at 12 midnight.

1901. **September** 4; Berkeley; 4:30 (?). Direction, east to southeast; light shock.

1901. **September** 17; San Jacinto.

1901. **September** 21; Branscomb.

1901. **September** 22; Branscomb.

1901. **September** 23; San Jacinto.

1901. **October** 12; Berkeley; 4:35 p. m. light shock.

1901. **October** 13; Mills College.

1901. **October** 29; Oakland, Peachland, Santa Rosa, Sonoma.

Napa; 4:36 p. m.—W. H. Martin.

San Francisco; 4:32 p. m.—A. G. McAdie.

1901. **November** 8; Lick Observatory; 7:34:28 p. m.

1901. **November** 13; Chico; 7 p. m. Intensity III.

1901. **November** 16; Laguna Valley.

1901. **November** 23; Santa Paula.

1901. **December** 11; Campbell, Lick Observatory, San José, Santa Cruz.

Berkeley; 0:53:20 p. m. Direction north to south. Again at 1:14 p. m. Record on duplex. Again at 1:58:59 p. m. Felt by J. W. M.

1901. **December** 14; Antioch, Mills College, Oakland, Rio Vista, Stockton, San Leandro.

Oakland, Chabot Observatory. Observer, Prof. Burckhalter. 8:13:50 a. m. Duration, 6 seconds; direction, northwest to southeast; in-intensity III. First two seconds, motion gyratory; last four seconds, short and horizontal.

Niles; 8:15 a. m.—Wm. Barry.

Napa; 8:14 a. m.—W. H. Martin.

San Francisco; 8:14:00 a. m.—A. G. McAdie.

Berkeley; 8:14:01 a. m. Direction, east to west; maximum displacement of the earth, 0.02 of an inch.

1901. **December** 15; Antioch, Oakland, San Francisco, San Leandro.

Berkeley; 12:11:10 p. m. Maximum displacement from east to west; probably less than 0.3 mm. No displacement in vertical or north to south.

1902. **January** 7; Oakland.

1902. **January** 22; Cuyamaca.

1902. **January** 27; Berkeley; 5:30 a. m.

1902. **February** 7; Santa Barbara.

1902. **February** 9; Pine Crest, San Luis Obispo.

Berkeley; 8:45 a. m. Displacement of earth particle, one millimeter toward the northwest.

1902. **February** 10; Berkeley; 7:41 a. m. Displacement, 0.27 mm. due west.

1902. **February** 20; Vacaville.

1902. **March** 16; North San Juan.

1902. **March** 23; Iowa Hill.

1902. **April** 2; Cuyamaca, Escondido.

1902. **April** 6; San Luis Obispo.

1902. **April** 9; San Jacinto.

1902. **April 13**; San Francisco; 5:49:43 a. m., few tremors; 2:59:55 p. m., two sharp jars; 3:04:50 p. m., light.—A. G. McAdie.

1902. **April 19**; Berkeley; 8:09:09 a. m. Direction northwest to southeast; displacement, 0.17 mm.

1902. **April 19**; San Francisco; 8:08:30 to 8:08:40 a. m. Short waves from west to east.—A. G. McAdie.

Mills College, San Jacinto, San Leandro.

Oakland, Chabot Observatory. Observer, Prof. Burckhalter; time, 8:09:02 a. m.; duration, 4 seconds; direction, east to west; intensity III.

Niles; 8:11 a. m.—Wm. Barry.

Napa; 8:10 a. m. Short, sharp jar.—W. H. Martin.

1902. **April 27**; Cuyamaca, Hollister.

1902. **May 1**; Campo, Laguna Valley.

1902. **May 2**; Campo, Laguna Valley.

1902. **May 19**; Berkeley; 10:31:20-40 a. m. Direction northwest to southeast; displacement, about 0.74 mm.

1902. **May 19**; Antioch, Calistoga, Colusa, Dixon, Dunnigan, Elmira, Guinda, Healdsburg, Ione, Iowa Hill, Lodi, Nevada City, Petaluma, Point Richmond, Rio Vista, Sacramento, Santa Rosa, Sonoma, Stockton, Suisun, Vacaville, Vallejo, Winters, Woodland. (Quite heavy shocks on the 19th in the central and northern portion of the State.)

Oakland, Chabot Observatory. Observer, Prof. Burckhalter; time, 10:30:36 a. m.; duration, 16 seconds; direction, circular; intensity IV.

Napa; 10:32 a. m. Short, heavy shake.—W. H. Martin.

San Francisco; 10:31:20 a. m. to 10:31:40 a. m. Movements up and down; duration, 20 seconds.—A. G. McAdie.

1902. **May 20**; Antioch, Elmira, Nevada City, Rio Vista, Sacramento, Suisun, Vacaville.

Napa; 10:20 p. m. Short, heavy roll.—W. H. Martin.

San Francisco; 10:22:15 p. m.—A. G. McAdie.

1902. **May 21**; Santa Ana, Sacramento.

1902. **May 25**; Winters.

1902. **June 3**; Branscomb.

1902. **June** 6; Keeler.

1902. **June** 9; Campo, Láguna Valley.

Berkeley. Light shock about noon.

1902. **June** 10; Campo, Imperial, Laguna Valley, Lowe Observatory, Redlands, San Bernardino, San Diego.

1902. **June** 20; Imperial.

1902. **July** 12; Cuyamaca.

1902. **July** 13; Redlands.

San Francisco; 6:21 a. m.—A. G. McAdie.

1902. **July** 21; Pine Crest, Upper Lake.

1902. **July** 22; Upper Lake.

1902. **July** 23; Ukiah, Willits.

1902. **July** 25; Willits.

1902. **July** 27; Berkeley; 5:08:21 a. m.

Lompoc; 10:55 p. m.

1902. **July** 28; San Luis Obispo.

Berkeley. Direction, south to southeast; very slight shock; displacement, 0.08 mm.

1902. **July** 30; Severe shocks occurred from the 27th to the 31st at Lompoc, Los Alamos, San Luis Obispo, Santa Maria, and other places in Santa Barbara and San Luis Obispo counties. A few buildings were thrown down, but the property loss was not great and no lives were lost.

1902. **July** 31; Berkeley. Very light shock.

Los Alamos; 7:30 p. m.

1902. **August** 1 to 3; Los Alamos. Several shocks.

1902. **August** 4; Los Alamos.

1902. **August** 11; Livermore, Oakland.

Niles; 6:10 a. m.—Wm. Barry.

San Francisco; 6:09:09 a. m.—A. G. McAdie.

Berkeley; 6:09:04 a. m. Southwest; displacement, 0.10 mm.

1902. **August** 14; Los Alamos.

1902. **August** 15; Imperial.

1902. **August** 24; Laguna Valley.

1902. **August** 28; San Luis Obispo.

1902. **August** 31; San Luis Obispo.

1902. **September** 1; Tequisquita Rancho.

1902. **September** 3; Tequisquita Rancho.

1902. **September** 10; Rohnerville.

Los Alamos; 9:30 to 11 p. m.

1902. **September** 17; Napa.

1902. **September** 18; Mills College, Mt. Tamalpais, Napa, San Rafael, Santa Rosa.

Oakland, Chabot Observatory. Observer, Prof. Burckhalter; time, 3:50:15 a. m.; duration, 8 seconds; direction, (?); intensity III.

San Francisco; 3:51:07 a. m. Shock lasted 3 seconds; direction, north and south.—A. G. McAdie.

Berkeley; 3:51 a. m. Lasted several seconds.

1902. **September** 23; Oakland, Chabot Observatory. Observer, Prof Burckhalter; 5:31 a. m.; intensity II.

San Francisco; 5.33 a. m.—A. G. McAdie.

1902. **September** 25; Berkeley; 8:53 a. m. Direction, southeast; displacement, .03 mm.

1902. **October** 21; Lompoc, Los Alamos.

1902. **October** 29; Berkeley. Direction, southwest; light shock; displacement, .2 mm.

1902. **November** 1; Los Angeles, San Diego, San Jacinto, Santa Ana.

1902. **November** 2; Berkeley; 7:52 a. m. Light shock. Displacement, .77 mm.

1902. **December** 2; Kerby, Oregon; 2 a. m. Slight shock.—E. F. Meissner.

1902. **December** 4; Hood River, Oregon, between 8 and 9 p. m. Observer, J. Hengst.

1902. **December** 12; Lompoc, Los Alamos, San Luis Obispo, Santa Barbara.

1902. **December** 18; Fox Valley, Linn County, Oregon, 7 a. m., two distinct shocks.—C. D. Wilson.

1902. **December** 27; San Jacinto.

1902. **December** 28; Greenville.

1903. **January** 3; Cuyamaca.

1903. **January** 7; Bakersfield; 4:30 p. m.

1903. **January** 11; San Luis Obispo.

1903. **January** 17; Imperial.

1903. **January** 23; Phœnix, Arizona. Slight shock about 10 p. m.—U. S. Weather Bureau.

1903. **January** 23; Yuma, Arizona. A heavy jolt or shake occurred at 9:30 p. m.—S. Hackett, U. S. Weather Bureau.

1903. **January** 23; Cuyamaca, Los Angeles, Ogilby, Poway, Santa Ana.

1903. **January** 23; San Diego; 9:29:46 p. m. Intensity III R.-F.; vibration, northeast to southwest.—F. A. Carpenter.

1903. **February** 4; Cuyamaca.

1903. **February** 8; Greenville.

1903. **February** 11; Cuyamaca.

1903. **February** 15; Rohnerville.

1903. **February** 25; Eureka. Slight earthquake shock occurred at 8:14 a. m. The vibrations appear to have been from southeast to north, and were of several seconds' duration. Barometer about 30:10, temperature about 50.

1903. **February** 27; Salinas.

1903. **March** 4; Santa Rosa.

1903. **March** 7; Gonzales.

1903. **March** 16; Campo.

1903. **March** 24; Gonzales, Santa Margarita.

1903. **March** 29; Oakland, Chabot Observatory. Observer, Prof. Burckhalter; 0:56:16 a. m.; duration, 7 seconds; direction, southwest to northeast; intensity III.

1903. **April** 18; Fort Ross.

1903. **April** 24; Santa Margarita.

1903. **April** 26; Dixon, Fort Ross, Napa, North Bloomfield, Rio Vista, Sacramento, Point Arena, 8 p. m., Woodland.

Napa; 5:20 a. m.—W. H. Martin.

Berkeley; 5:21:37 a. m. Direction, east to west; very light, lasting several seconds; again at 9:09 a. m., and again at 8:21:08 p. m.

1903. **May** 17; Berkeley; 1:50:59 a. m.

1903. **May** 21; San Jacinto.

1903. **June** 8; Lick Observatory; 9:59:33 (?). Intensity R.-F. I. A single tremor, followed by a faint vertical jolt. Reported only by Dr. Perrine. No record on instrument.

1903. **June** 11; Antioch, Boulder Creek, Brentwood, Elmwood, Farmington, Fort Ross, Haywards, Iowa Hill, King City, Livermore, Lodi, Los Banos, Los Gatos, Mills College, Mt. Tamalpais, Napa, Newman, Peachland, Petaluma, Rio Vista, Sacramento, Salinas, San Francisco, San José, San Leandro, San Luis Obispo, San Mateo, San Miguel, San Rafael, Santa Margarita, Santa Rosa, Sargent, Sonoma, Stanford University, Stockton, Tiburon, Vallejo, Watsonville.

Oakland, Chabot Observatory. Observer, Prof. Burckhalter; 5:11:41 a. m.; duration, 12 seconds; direction, east to west; intensity IV. Stopped the mean-time clock. First six seconds gentle, then for two seconds very feeble; then four seconds sharp gyratory, ending with extreme suddenness.

Campbell; 5:11:18 a. m., the most severe earthquake occurred at this station; duration, 60 seconds.

Niles. Two sharp earthquake shocks on June 11. The last one was very sharp, the most severe noticed since October 21, 1868. Time, 5:15 a. m.; observer, William Barry.

Santa Cruz. Heavy earthquake shock at 5:13 a. m.—W. R. Springer, Observer.

Napa; 5:13 a. m. Medium.—W. H. Martin.

Lick Observatory. Time of beginning, 5:11:22 a. m. Heavy wave for 6 seconds, gradually decreasing in force until about 20 seconds, when a second maximum occurred, but much less heavy than the first. Vibrations were easily noticeable until 32 seconds. Motion

in all directions. No very violent vibrations—*i. e.*, sharp, quick. House rocked uncomfortably, accompanied by some noises. Time of beginning probably 2 seconds late. R.-F. VI or VII. No wind. —C. D. Perrine.

1903. **June 11**; Lick Observatory. About 9:55 p. m., June 10, preceding the earthquake shock by 7 hours and 20 minutes, the mercury was so disturbed that for an interval of more than one minute absolutely no images were visible. At the time, this was attributed to some freak of the wind, which was, however, quite moderate and steady. Ordinarily little trouble is experienced from wind, even when violent, and then only for brief intervals. This disturbance was a continuous quiver which rendered all reflections impossible. Tremors previously noted as connected with earthquake shocks were usually of the nature of vibrations or oscillations.—Prof. R. H. Tucker.

Very severe quake. Good records on both instruments, but the Ewing clock did not start. The record of the clock beats was accordingly impressed later. The general direction of vibration was northeast and southwest, with a strong vertical component. There is evidence of gyratory motion which is clearly shown in the duplex record. The maximum oscillation of the earth's surface was 1/5", R.-F. VI or VII.—Prof. R. H. Curtiss.

Berkeley; 5:12 a. m. Severe shock.

1903. **June 20**; Berkeley; 1:10 a. m. (date probably wrong; possibly June 21, a. m).

1903. **June 21**; San Francisco.

Oakland, Chabot Observatory; 1:20 a. m.; duration, 10 seconds; direction, east to west; intensity II.

Napa; 1:30 a. m.—W. H. Martin.

1903. **June 26**; Campo, Cuyamaca, San Jacinto.

1903. **June 29**; Cuyamaca.

1903. **July 2**; Campo, Cuyamaca.

1903. **July 12**; Campo.

1903. **July 13**; Hollister, Campo.

1903. **July 24**; Chico, Colusa, Grass Valley, Greenville, La Porte, Marysville, Meadow Valley, Nevada City, Orland, Oroville, Palermo. Sacramento, Tehama, Wheatland, Willows.

(Willows. A severe shock of earthquake at 12:26 p. m. on the 24th, began with a rumbling noise, succeeded by a twister. Several brick walls cracked and plaster fell from many buildings.

The atmospheric conditions prevailing in the valley previous to the shock, as viewed by me from an elevation of 4,500 feet, were very peculiar.—A. W. Schorn.)

Magalia; c.20:50 p. m. VI.

1903. **July 30**; Elsinore, Redlands, Riverside, Salinas, San Bernardino, San Jacinto, Uplands.

(San Bernardino. The earthquake at 9 p. m. on the 30th was quite severe and lasted about twenty seconds.—Dr. A. K. Johnson.)

1903. **August 2**; Alameda, Boulder Creek, Calistoga, Campbell, Elmwood, Fresno, Hollister, Kentfield, Lick Observatory, Lodi, Mills College, Mount Tamalpais, Oakdale, Peachland, Rio Vista, Sacramento, Salinas, San Francisco, San José, San Rafael, Santa Cruz, Santa Rosa, Sonoma, Stockton, Suisun, Summerdale, Tequisquita Rancho, Yosemite Valley.

Oakland; Chabot Observatory. Observers, C. B. and S. W.; 10:49:29 a. m.; duration, 31 seconds; direction, south to north, east to west; intensity IV. There were two distinct shocks. The first, south to north, lasted about 20 seconds; then, after a quiet interval of 3 seconds, a shock from east to west lasted 8 seconds. Stopped mean-time clock 10:49:42 a. m.

Niles; 10:05 p. m. and 10:59 p. m.—Wm. Barry.

Napa; 10:42 p. m. Lively.—W. H. Martin.

Lick Observatory; 11:36:30 p. m.

1903. **August 2**; Lick Observatory. R.-F. VII or VIII. The most severe shock since the establishment of the Lick Observatory occurred on the night of Sunday, August 2, 1903. The time of beginning of the first shock was recorded by various observers as follows: 10:49:21—3 p. m.—Aitken; 10:49:21—Vogt; 10:49:15—Perrine. Smaller vibrations lasted a few seconds, followed by 15 or 20 seconds of very violent shocks, generally in an east-west direction. Strong vibrations continued 10 seconds longer. This shock proved too severe for the seismometers of the Lick Observatory. The duplex recorded the earlier vibration, but was thrown out of adjustment by the heavier shock. The Ewing plate failed to rotate, but the indicator moved about, practically with the result that the east-west pen was thrown entirely off the disk. The motion of the earth seems to have been about half an inch. None of the astronomical instruments suffered damage. Beyond numerous cracks in plastering, nothing will remain to betray the intensity of the disturbance. Several chimneys on brick houses toppled over. Evidence points to Hall's Valley as the probable center of seismic activity. As in the case of the shock of 1868, minor vibrations have been recorded at small intervals as follows: August 2, 11:36:30 p. m. R.-F. III. Light shock, lasting 1 or 2 seconds. August 3, 3:22:41 p. m. R.-F. II. Single vertical jolt. August 8, 4:17:14 p. m. R.-F. I; duration,

2 seconds: northeast to southwest; slow. August 10, 2:51:07 a. m. R.-F. II. Slight vibrations for about a second. August 10, 3:01:04. Further shocks have been suspected but unrecorded.—Dr. R. H. Curtiss.

1903. **August** 2; Lick Observatory; 10:49:21 p. m., perhaps 3 seconds late. Heavy shocks lasted 20 seconds, strong vibrations 10 seconds longer. Slight shock, lasting 1 or 2 seconds, at 11:36:30.—R. G. Aitken.

Time, 10:49:15. Heaviest waves lasted 15 seconds and some waves for 35 seconds. Plaster thrown down, ornaments, books, and bottles thrown to the floor; guns moved along the wall. A high north wind blowing at the time.—C. D. Perrine.

Clock No. 1 not disturbed. Clock No. 7 stopped at 10:49:24; started again August 3. Small weight shaken from pendulum shelf of No. 4. About 8 shot shaken from the pendulum rod of No. 3 and 1 from the cup of No. 8. A few drops of mercury also shaken from the pendulum of No. 8.—Elliott Smith.

Berkeley; 10:50 p. m.

1903. **August** 3; Lick Observatory; 3:22:41 p. m.

1903. **August** 4; Laguna Valley.

1903. **August** 8; Lick Observatory, San José; 4:17:14 p. m.; duration, 2 seconds; northeast to southwest; slow.—R. H. Curtiss.

1903. **August** 10; Niles, San Francisco, San José.

Niles; 2:50 a. m. and 3 a. m.—Wm. Barry.

Lick Observatory; 2:51:07 a. m.—J. D. Maddrill; 2:51:04 a. m.—R. H. Curtiss; 3:01:04 a. m., 3:01:11 a. m.—C. D. Perrine.

1903. **August** 13; Mills College, Oakland, San Francisco.

Oakland, Chabot Observatory. Observer, Prof. Burckhalter; 3:33:18 a. m., duration (?), intensity III. Motion was probably gyratory.

1903. **August** 14; Mills College; 5:49 a. m.

1903. **August** 24; Los Olivos.

1903. **August** 26; Lick Observatory; 7:51:41 to 45 p. m. R.-F. I. Reported by Dr. Perrine. Vibrations east and west.

1903. **August** 28; Lick Observatory; 3:40:08 to 10 p. m. R.-F. II. Duration, 2 seconds.

1903. **September** 16; **Los Angeles**. Light shock felt in city, but not at Weather Bureau.—A. B. Wollaber.

Santa Ana; 4:10 a. m. VI.

1903. **September** 16; Anaheim, Elsinore, Fall Brook, Los Angeles, Redlands, Riverside, San Bernardino, San Jacinto, Santa Ana, Sierra Madre.

1903. **September** 18; Lick Observatory; 11:37:01 p. m. R.-F. I. Vertical. Reported by C. D. Perrine.

1903. **September** 21; Redlands.

1903. **September** 24; Rohnerville.

1903. **September** 30; Ukiah.

1903. **October** 4; Cuyamaca.

1903. **October** 13; Lick Observatory; 6:02:50 a. m. Reported by Mr. Albrecht.

1903. **November** 18; Imperial (severe).

1903. **December** 9; Eureka. Quite a severe shock occurred at 8:44 a. m. It came in two successive jolts of several seconds duration; the vibrations, apparently from southwest to northeast, being of sufficient violence to shake considerably the building in which is located the Weather Bureau office and to stop clocks in different parts of the city.

1903. **December** 14; Riverside.

1903. **December** 15; Yosemite.

1903. **December** 18; Claremont.

Lick Observatory; 5:20:50 to 53 (?). R.-F. III or IV. Preliminary tremors followed by a heavy jar which appeared to be principally in the vertical.—C. D. Perrine.

Berkeley; 5:21:15 p. m. Light shock.

Santa Cruz.

1903. **December** 21; Redlands, San Bernardino.

1903. **December** 25; Pasadena, Riverside, San Bernardino, Sierra Madre.

Los Angeles. Quite heavy shock at 9:45 a. m.—U. S. Weather Bureau.

1903. **December** 31; Yosemite.

1904. **January** 10; Fort Ross, Healdsburg, Mercury.

1904. **January** 11; Rohnerville.

Eureka. Very light earthquake was felt at 11:14 p. m. Barometer about 30:35, temperature about 46°.

1904. **January 21**; Ukiah.

1904. **January 22**; Los Alamos.

1904. **January 23**; Los Alamos.

1904. **January 26**; Tequisquita Rancho.

1894. **February 15**; Healdsburg.

Lick Observatory; 12:49:58 p. m., duration 2 seconds. R.-F. II. Mostly in the horizontal. Reported by Dr. Perrine; 10:03:56 p. m. R.-F. I. Single, rather long swing noted by Dr. Perrine. Duplex record northeast, 1.1 mm.; displacement, 0.12 mm.

1904. **February 22**; Kentfield, Mount Tamalpais, San Francisco, San José, San Mateo, Sonoma.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 3 a. m., intensity II.

Napa; 3:30 a. m.—W. H. Martin.

Mills College; 3:00 a. m.—Josiah Keep.

Berkeley; 3:00 a. m.

1904. **February 25**; Campbell.

1904. **March 1**; San Francisco, San Mateo, Sonoma.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 6:09 a. m., intensity II.

Niles; 6:09 a. m.—Wm. Barry.

Napa; 6:00 a. m.—W. H. Martin.

Mills College; 6:10 a. m.—Josiah Keep.

1904. **March 5**; San Mateo.

1904. **March 12**; Branscomb, Fort Bragg, Willits.

1904. **March 15**; Branscomb, San Mateo.

1904. **March 16**; Seattle, Wash.; 8:20 p. m., intensity III; duration 15 seconds; vibrations east to west. This shock was felt generally over western Washington.—Weather Bureau.

1904. **March 18**; Campo.

1904. **March 26**; Eureka. Quite a heavy shock occurred at 3:53 p. m., lasting about 10 seconds. The vibrations were from southwest to northeast. Barometer about 30:00, temperature about 50°.

1904. **April 2**; Lick Observatory. First shock 11:39:25 a. m., light; second shock 11:39:29 a. m., a little heavy; direction northwest to southeast principally.—Dr. W. W. Campbell.

1904. **April 4**; Berkeley; 7:10:10 p. m. Northeast to southwest. Displacement, 0.25 mm.

1904. **April 13**; San Francisco.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 5:15:23 p. m., intensity II.

1904. **April 15**; Shasta. Probably 16th.

1904. **April 16**; Redding; 1:20 a. m.

1904. **April 21**; Aptos, Boulder Creek, Campbell, Hollister, Los Gatos, Mills College, Mt. Tamalpais, San Francisco, San José, San Mateo.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 3:51:10 a. m., intensity II.

Niles; 3:44 a. m.—Wm. Barry.

Lick Observatory; 3:55 a. m.—E. Smith.

1904. **May 1**; Los Angeles, Ventura; 10:30 a. m. IV.

1904. **May 3**; Hollister.

1904. **May 6**; Cloverdale.

1904. **May 8**; Ukiah.

1904. **May 11**; Lick Observatory; 5:16:27 a. m. ± 1 second. R.-F. III, chiefly horizontal. Shock lasted about 3 seconds. Duplex record, slight.—Dr. Perrine.

1904. **May 19; San Francisco.**

Niles; 1:30 a. m.—Wm. Barry.

1904. **June 3**; Imperial.

1904. **June 22**; Lick Observatory; 11:25:53 (?). Slight. R.-F. I, lasting 2 or 3 seconds.—C. D. P.

1904. **June 26**; Cuyamaca.

1904. **July 6**; Branscomb, Eureka. Light earthquake reported to have occurred in early morning. Barometer about 29:96, temperature about 54°.

19004. **July 9**; Lick Observatory; 12:34:40 p. m. Vertical jolt followed by slight east and west tremors.

1904. **July** 14; Campo.

1904. **July** 21; Livermore, San Francisco.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 11:25 p. m., intensity II.

Berkeley; 11:25:03 p. m.

1904. **July** 30; Rio Vista, Sacramento, San Francisco, Santa Rosa, Stockton, Woodland.

Napa; 2:29 a. m.—W. H. Martin.

Berkeley; 2:25:37 a. m., east to west, very light.

1904. **August** 2; Calistoga; 9:50 a. m. III.

1904. **August** 3; Lick Observatory; 8:10:10 p. m. Light.

1904. **August** 5; Lick Observatory; 5:43:08 p, m. Duration 4 seconds of varying intensity. R.-F. I to III.—W. W. C.

1904. **August** 11; Fort Ross.

1904. **August** 21; Healdsburg.

1904. **August** 27; Oakland, Chabot Observatory. Observer, S. W.; 0:59:03 p. m., intensity II.

Lick Observatory; 12:58:47 p. m. Duration 4 seconds. R.-F. V or VI. A second light shock at 12:58:55. Complete records obtained on both the Ewing and duplex seismographs.

1904. **September** 8; Campo, Cuyamaca, Imperial, San Diego.

1904. **September** 9; Campo, Riverside.

1904. **September** 10; San Luis Obispo.

1904. **September** 12; Imperial.

1904. **September** 13; Campo.

1904. **September** 14; Eureka. Light shock occurred at 9:33 a. m., lasting about 10 seconds. The vibrations were from southwest to northeast. Barometer about 30:08, temperature about 51°.

1904. **September** 28; Imperial.

1904. **September** 30; Campo, Tequisquita Rancho.

1904. **October** 11; Berkeley; 2:48:54 p. m.

1904. **October** 13; Berkeley; 4 p. m.

1904. **October** 14; Snedden Ranch, Ventura.

1904. **October** 15; Santa Barbara, Sierra Madre.

Los Angeles. Light shock is said to have occurred.

Berkeley; 2:48:54 p. m.

1904. **October** 20; Snedden Ranch.

1904. **October** 25; Bishop, Campo, Cuyamaca, Laguna Valley.

1904. **October** 27; Campo, Cuyamaca, Laguna Valley.

1904. **October** 29; Brush Creek.

1904. **November** 22; San Francisco; 7:7:46 a. m.

1904. **November** 23; San Francisco.

1904. **November** 25; Oakland, Chabot Observatory. Observer, Professor Burckhalter; 5:50:40 a. m., intensity II.

1904. **November** 26; Cuyamaca, Mills College, Oakland, San Francisco.

1904. **November** 27; San Francisco.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 8:20:27 a. m. Duration few seconds; direction southwest to northeast, intensity II.

1904. **December** 1; Lick Observatory. At about 8 o'clock a record was found on the plate of the duplex. No report of the shock was turned in.—Dr. J. H. Moore.

San Francisco, San Rafael.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 1:00:01 a. m. Duration 8 seconds; direction southwest to northeast, intensity IV. 1:04:23 a. m. Duration 3 seconds; direction southwest to northeast, intensity III. 1:09 a. m. Direction southwest to northeast, intensity III. 1:10 a. m. Direction southwest to northeast.

Berkeley; 1:07:10 a. m. Direction north to south.

Napa; 1:00 a. m.—W. H. Martin.

1904. **December** 2; San Francisco.

1904. **December** 3; San Francisco.

Lick Observatory; 7:56:12 p. m. Shock severe enough to rattle windows; lasted about 1 or 2 seconds; preceded by a warning noise so that I was expecting it for about 2 seconds.—Dr. W. W. Campbell.

1904. **December** 4; Rohnerville, San Francisco.

Eureka. Quite a severe earthquake shock occurred at 0:20 a. m., lasting about 10 seconds. The vibrations, apparently, were from south to north. Barometer about 30:04, temperature about 52°.

1904. **December** 5; San Francisco.

1904. **December** 7; San Francisco.

1904. **December** 8; Mills College, San Francisco.

1904. **December** 9; San Francisco.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 3:40 p. m., intensity II.

1904. **December** 11; San Francisco.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 11:52:50 a. m., intensity II.

1904. **December** 14; Berkeley, Campbell, Idyllwild, Mills College, Peachland, San Francisco, San José, San Leandro, San Rafael, Santa Rosa, Sonoma.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 7:09 a. m. Duration 4 seconds; direction northeast to southwest, intensity II.

Niles; 7:10 a. m.—Wm. Barry.

Napa; 7:15 a. m.—W. H. Martin.

Lick Observatory. Light shock 7:10 a. m., reported by K. Burns.

1904. **December** 16; San Francisco.

1904. **December** 17; Idyllwild.

1904. **December** 20; Lick Observatory. Light shock, 11:47:28 a. m.—K. Burns and J. H. Moore.

1905. **January** 1; San Francisco. A number of shocks reported by Weather Bureau. Professor McAdie's personal record gave times of occurrence of ten or more perceptible shocks on this date. This record was destroyed by fire April 18-21, 1906. These note books gave the times for a large number of earthquakes during 1904 and 1905.

Berkeley; 3:38 p. m., southwest to northeast.

Lick Observatory; 3:37:51 p. m. III or IV. 4:25:16 p. m. I or II.

Napa; 3:45 p. m.—W. H. Martin.

Niles; 3:30 p. m.—Wm. Barry.

1905. **January** 1; Mills College, Mount Tamalpais, Niles, San Francisco, Sausalito.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 10:30 a. m. Duration 2 seconds, intensity II. 3:27:50 p. m. Three seconds' duration; direction east to west, intensity III. 4:25:18 p. m., intensity II.

1905. **January** 2; San Francisco, Sausalito.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 10:04 p. m. Duration 3 seconds; direction northeast to southwest, intensity III.

Lick Observatory. 10:22:37 to 41 p. m.

1905. **January** 3; San Francisco, Sausalito.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 2:37:40 a. m. Duration 10 seconds; direction northeast to southwest, intensity III. About twenty vibrations in 10 seconds.

1905. **January** 4; Sausalito.

1905. **January** 5; Sausalito.

1905.—**January** 6; Angiola, Claremont, Lone Pine, Mills College, Sausalito, Wasco.

1905. **January** 7; Fort Bragg.

1905. **January** 8; Oakland, Chabot Observatory. Observer, Professor Burckhalter; 1:09:45 p. m. Duration 6 seconds; direction northeast to southwest, intensity II.

1905. **January** 9; Cuyamaca.

1905. **January** 11; San Francisco.

1905. **January** 23; Fort Bragg.

Berkeley. Light shock during the night.

Lick Observatory; 9:38:44 a. m. II.

1905. **January** 25; Cloverdale.

1905. **February** 4; Claremont.

1905. **February** 13; Cloverdale.

1905. **February** 22; Oakland, Chabot Observatory. Observer, Professor Burckhalter; 8:36 p. m., intensity II.

1905. **February** 23; Lick Observatory; 9:38:44 a. m. Preceded by a rumble. Intensity R.-F. II.—Professor Campbell.

1905. **March** 7; Imperial.

1905. **March** 12; Cloverdale.

1905. **March** 18; Bakersfield, Isabella, Nordhoff, San Francisco, Wasco; 8:40 p. m. VI.

1905. **March** 24; Cloverdale.

1905. **April** 3; Boulder Creek, Hollister, Salinas, San José, Santa Cruz; 2 a. m.

1905. **April** 4; Boulder Creek, Hollister, Salinas, San José, Santa Cruz.

Niles; 2:25 a. m.—Wm. Barry.

Lick Observatory. Light shock 2:23:00 a. m., lasting about 3 seconds, followed by a second shock of equal intensity, also lasting about 3 seconds. Records obtained from both instruments.—E. Smith.

1905. **April** 17; Redding.

1905. **April** 18; San Francisco.

1905. **April** 19; Santa Cruz.

1905. **April** 23; Calexico, Campo, Idyllwild, Imperial.

1905. **April** 24; Point Loma.

1905. **April** 27; Boulder Creek, Imperial, San Francisco, Santa Cruz.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 9:10 p. m., intensity II.

Niles; 9:53 p. m.

1905. **April** 28; Niles; 12:25 a. m.—Wm. Barry.

Lick Observatory. Light shock. Ewing record shows slight motion north-south and east-west. No vertical motion; 9:41:17 a. m.

1905. **April** 29; Hollister, Riverside, Ventura.

1905. **April** 30; Idyllwild.

1905. **May** 6; Lick Observatory. Light shock accompanied by a rumbling noise; 12:01:20 p. m. No records on instruments.

1905. **May** 10; Zenia.

1905. **May** 15; Nevada City, Oakdale, Yosemite.

1905. **May** 16; Yosemite.

Berkeley; 7:50 p. m.

1905. **May** 19; Sacramento. Light shock at 4:59 p. m.

1905. **May** 23; Independence. Feeble shock at 6:50 p. m. Also noted at Bishop.

1905. **May** 25; San Luis Obispo. Light shock, east to west. Duration 3 seconds; 9:49 p. m.

1905. **May** 25; Elmwood, Huron, Lone Pine, Los Gatos, Sacramento, Salinas, San Francisco, Santa Cruz, Soledad, Summerdale, Yosemite; 6:50 p. m. V.

1905. **May** 26; Lick Observatory. Noticed by no one; recorded by Ewing and duplex; 6:53:12 a. m. Second shock 11:55:11 a. m. Rumbling heard. No record on instruments.

1905. **June** 11; Calexico.

1905. **June** 12; Campo.

1905. **June** 18; Napa.

1905. **July** 13; San Francisco.

1905. **July** 15; Riverside, San Bernardino; 12:41 p. m. VII.

1905. **July** 20; Fort Ross.

Lick Observatory. Light shock. Single vertical jar, distinctly felt; 9:16:39 p. m.—J. D. Maddrill.

1905. **August** 8; San Francisco.

1905. **August** 11; Campo.

1905. **August** 15; Branscomb.

1905. **August** 21; Campo.

1905. **August** 22; San Francisco.

1905. **August** 25; Imperial.

1905. **August** 31; San Francisco.

1905. **September** 2; Pasadena, Sierra Madre.

Los Angeles. Sharp shock at 8:39 p. m.—U. S. Weather Bureau.

1905. **September** 5; Idyllwild.

1905. **September** 16; Fruitvale, San Francisco.

1905. **September 26**; San Francisco.

Niles; 6:35 a. m.—Wm. Barry.

1905. **October 14**; Santa Rosa.

1905. **October 21**; Lick Observatory. Slight shock at 3:52:25 p. m.; record on the Ewing.

1905. **November 7**; Branscomb.

1905. **November 9**; Claremont.

1905. **November 14**; Calexico, Imperial.

1905. **November 22**; Lick Observatory; 11:49:24 p. m. Preceded by a slight rumble.

1905. **November 26**; San Francisco.

1905. **November 27**; San Francisco.

1905. **November 28**; San Francisco.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 11:24:52 a. m. Duration 2 seconds; direction northeast to southwest, intensity II.

1905. **December 3**; Imperial, Mills College, San Francisco; 11:30 a. m.

Oakland, Chabot Observatory. Observer, Professor Burckhalter; 11:25:58 a. m. Duration 3 seconds; direction southwest to northeast, intensity III.

Niles; 11:23 a. m.—Wm. Barry.

1905. **December 15**; Mercury.

1905. **December 18**; Mills College, San Francisco; 11:59 p. m.

Oakland, Chabot Observatory. Observer, S. W.; time, midnight. Direction northwest to southeast.

1905. **December 19**; San Francisco.

Lick Observatory. Light shock; 12:51:19 a. m. Possibly same as December 18.

1905. **December 23**; Bakersfield, Tejon Rancho, Wasco. At 2:23 p. m.

1905. **December 28**; San Francisco.

1906. **January 2**; Spokane, Wash. Light shock at 5:55 a. m. Motion from east to west.—C. Stewart, U. S. Weather Bureau.

1906. **January** 14; Mono Ranch.

1906. **January** 16; San Francisco; 10:33 a. m. and 2 p. m. Feeble shock.—A. G. McAdie.

1906. **January** 17; Lick Observatory; 12:46:56 a. m. Two light shocks, about 1 second apart. No instrumental record.

1906. **January** 25; Phœnix, Arizona; 1:40 p. m. Marked tremors and rocking motion; north to south. This same shock, but more violent, felt at Flagstaff, Ariz.—L. N. J., Weather Bureau.

1906. **January** 31; Mills College.

San Francisco; 10:58 p. m.—A. G. McAdie.

1906. **February** 26; Lick Observatory; 5:24:40 a. m. Two light shocks, about a second apart. Duplex gave slight displacement to the west.

1906. **March** 3; Calexico, Campo, Cuyamaca, El Cajon, Riverside, Point Loma.

San Diego; 12:24:50 p. m. Force II; direction southwest to northeast.—F. A. Carpenter.

1906. **March** 4; Calexico, Cuyamaca.

1906. **March** 5; San Francisco; 9:30 p. m.—A. G. McAdie.

1906. **March** 19; Napa.

1906. **March** 20; Cuyamaca.

1906. **April** 11; Niles; 12:54 a. m.—Wm. Barry.

1906. **April** 18; San Francisco.

THE SAN FRANCISCO EARTHQUAKE.

By Prof. A. G. McADIE, U. S. Weather Bureau.

The morning of Wednesday, April 18, was clear and pleasant over the greater portion of the Pacific coast. An area of high pressure was moving steadily and somewhat slowly eastward over Idaho. The weather map gives the conditions existing a few minutes previous to the great earthquake, and it may be noted that the pressure distribution is of a type which has been found to prevail when certain earthquakes occur in California. A study of the relation of atmospheric pressure and earth movement had been under way in the office of the Weather Bureau at San Francisco for some years, and while no very definite conclusions had been arrived at, it was plain that the greater number of earthquakes

in California occurred apparently without any relation to pressure distribution. It was noticed, however, that some earthquakes occurred during the passage of a marked "high" across the northern portion of the coast. While any relation of this character must be obscure and indefinite, it is conceivable that in a region where quakes and tremors of tectonic origin are frequent—that is, a region where strata are in unstable equilibrium—the passage of an area of high pressure may directly or indirectly affect the stresses at critical times. The relation is involved and is alluded to here only because at Manila and Tokyo microseismic phenomena bear some relation to approaching typhoons: The thought suggests itself that the installation of seismographs on the Pacific coast may lead to the detection of advancing pressure areas.

The earthquake, as timed by the writer, began at 5:13:05 a. m., 120th meridian time. The disturbance lasted for about 40 seconds. The main shock was followed by others. The times are:

April 18, 1906, 5:13:05–45 (?), severest known in San Francisco.
" " 5:19:10 a. m., feeble.
" " 5:21 a. m., feeble.
" " 5:26 a. m., feeble.
" " 5:43 a. m., feeble.
" " *[6:06—6:30—6:42 and 6:56 light].
" " 8:14:28 to 8:14:33, sharp, twisting motion.
" " *[8:19—8:42].
" " 9:14 a. m., sharp, short.
" " 9:26 a. m., moderate.
" " *[9:48 and 10:05].
" " 10:50 a. m., moderate.
" " 11:06 a. m., moderate.
" " *[11:47].
" " 12:04 p. m.
" " 12:11 p. m., very light.
" " 2:24 p. m., very light.
" " 2:28 p. m., very light.
" " 4:51 p. m., very light.
" " 6:50 p. m., very light.
" " 7:01 p. m., very light.
April 19, 1906, 3:07:00 a. m., light.
" " 1:13 p. m., sharp, main portion with twist.
April 20, 1906, 4:45:00 a. m., tremor.
" " 5:31 a. m., moderate.
" " 7:15 a. m., moderate.
April 21, 1906, 6:28 a. m., strong.
April 22, 1906, 7:03:00 a. m., light.
" " 3:19:30 p. m. to 3:19:34 p. m., moderate, rocking.
April 23, 1906, 12:05:00 a. m., lasted about 3 seconds.
" " 3:51 p. m., sharp, downward jolt.
" " 10:34 p. m., moderate.

*[Obtained by voltmeter diagrams furnished by Mr. Nelson Eckart.] All other times by the writer.

April 24, 1906, 1:25 a. m., short.
" " 1:32 a. m., tremors.
" " 1:14 p. m.
April 25, 1906, 4:30 a. m.
" " 3:17:10 p. m., double waves recorded on seismograph.
April 27, 1906, 1:07 p. m.
April 29, 1906, 4:09 p. m.
April 30, 1906, 1:57:30 a. m.
" " 1:59:40 a. m., single swing.
" " 7:10 a. m.

Numerous shocks, mostly light, occurred in May, especially during the first two weeks.

The initial disturbance on April 18, from 5:13:05 to 5:13:45(?) a. m., consisted of heaving, throwing, and racking motions sufficiently intense to dislodge cornices, crack walls, break chimneys, and wrench solid masonry. On made ground and in alluvial soil, crevices and cracks of varying width were opened. While the destruction was great and considerable débris filled the streets, it was noticed that buildings on the hills apparently suffered less than those on lowlands; also that the steel buildings, known as Class A, as well as heavily built stone buildings, were practically intact after the shock. At the office of the Weather Bureau, on the tenth floor of the Mills building, the instruments there and on the roof (12th floor) were examined before 7 a. m. and found to be all in working order, except that the anemometer support had been shaken down. The thermograph on the roof and the telethermograph and barograph in the office showed a displacement of the pens of about 0.75 of an inch on each side, or 1.5 inches in all. Within a few minutes after the shock fire broke out in many parts of the city. For four days the fire raged. About 520 city blocks, or 3,000 acres, were burned, 25,000 buildings were destroyed, one-half of which were residences, ninety-five square miles were devastated, and more than 100,000 people rendered homeless. The financial loss has been estimated at $350,000,000. The insurance loss was estimated at $235,000,000. About 400 lives were lost.

The earthquake was felt distinctly at Eureka and as far south as Los Angeles.* The line of greatest intensity appears to be along one of the old faults running from Mussel Rock southeast through Lake San Andreas, Crystal Springs, Stevens Creek, Campbell Creek, Wrights and Skyland. This is generally known as the San Andreas fault. Dr. John C. Branner, of Stanford University, fortunately made an extensive and detailed survey of the Santa Cruz section shortly before the slip, and has been able to promptly resurvey this section of greatest dislocation. He is of the opinion that the slipping of the fault is plainly shown by surface conditions, especially by tree destruction. Near Loma Prieta he found along the line of the fault marked destruction of trees. "The forest looked," he says, "as though a swath had

* A shock was felt at San Diego at 4:30 p. m., April 18, but was probably an after shock.

been cut through it two hundred feet in width." In a little less than a mile he counted no less than 345 cracks running in every conceivable direction. A marked displacement of the pipe lines of the Spring Valley Water Company also indicates a slip of the San Andreas fault. Prof. A. C. Lawson, of the University of California, has shown that the San Francisco peninsula has at least three well-marked faults. Some of these, especially the San Bruno fault, traverse the Gulf of the Farallones and the northern peninsula. It must not be forgotten that the earthquake wrought great damage in Marin, Sonoma, Napa, Lake, Mendocino, and Humboldt counties. At Santa Rosa the destruction was very great.

No tidal wave or disturbance in the water of any character followed the earthquake. The waters of San Francisco Bay were unusually calm throughout the forenoon of April 18.

A number of valuable records have been made on seismographs, of the Omori horizontal pendulum type, of the earth waves at various points. In the Weather Bureau at Washington, D. C., the record obtained by Professor Marvin of an east and west motion showed that the preliminary tremors lasted for six minutes before the larger wave motions were recorded. At Tokyo the duration of these first preliminary tremors was nine minutes and forty-nine seconds; at Birmingham, England, about twenty-five minutes. Other records have been obtained at eight or nine stations where seismographs have been installed, and in due time data will be published showing the probable origin and nature of the earth dislocation. This, it is thought, will be a line or plane rather than a definite point or centrum. From the duration of the tremors the approximate arcual distance between the seismograph and the origin, can be determined.

1906. **April 18**; San Francisco Bay. Captain R. Peterson, German steamer "Uarda," of Kosmos line, reports: "5:05 a. m., off the Golden Gate, near the middle buoy, felt a sharp earthquake lasting from 3 to 4 minutes, causing every one on board to think that we had struck a rock or submerged wreck. Sounding 8½ fathoms and afterwards 5 fathoms. While at anchor in San Francisco Bay felt shocks all day."

NOTE.--This steamer also experienced the Valparaiso earthquake of August 16, 1906, at 8:10 a. m.; also after shocks, August 17 and 18, while lying at anchor in harbor of Valparaiso.

1906. **April 18**; Oakland, Chabot Observatory. Prof. Charles Burckhalter; duplex pendulum seismograph; 5:12:51 a. m.; duration 48 seconds; directions all possible; intensity VIII-IX. Pendulum of sidereal clock wrecked; mean-time clock pendulum jammed behind arc; clock stood at 5:14:48, but experts believe clock raced two minutes. Gravity escapement. Second severe shock 8:19:20, duration 5 seconds; direction northeast to southwest; intensity V. Fifteen additional shocks by 1 p. m., duration from 2 to 5 seconds; directions east to west; intensities II to IV. Three shocks be-

tween 1 and 3 p. m. Five shocks between 3 p. m., April 18, and 6 a. m., April 19.

Niles; 5:15 a. m.—Wm. Barry.

Lick Observatory; 5:12:45 a. m. Duration of record on the Ewing seismograph 3 minutes 45 seconds. A large number of reports are to be found in the observatory record.

''Duration of (the 5:12) shock about 30 seconds; vibrations stopped in house at end of that time. Heaviest shock 11 seconds after start, shocks coming about one a second. Heaviest R.-F. VIII; northwest to southeast. First secondary maximum about 5 seconds after beginning—maximum 11 seconds after beginning. Another secondary maximum about 15 or 20 seconds from beginning, accompanied by sound as of flight of birds; no rumbling; no vertical component. (Other shocks during same day:) 6:46:34 a. m. R.-F. II. 9:16:52 a. m. R.-F. III. 11:53:37 a. m. R.-F. III, vertical. 6:51:58 p. m. R.-F. II, vertical.''—K. Burns.

''Time of heaviest shock 5:12:45 a. m. Eight slight shocks felt in the half hour following. Also one at 6:30 a. m., 6:45 a. m., 8:15 a. m., 9:30 a. m., and one other between 6:45 and 8:15 a. m.''—R. G. Aitken.

''Time 5:12:19 a. m. At first a jar, then a perceptible pause, then a tremble. Counted up to 25 seconds positively, then continued mechanically. I would put the time of duration between 30 and 35 seconds. Heard no sound preceding the shake. Other shocks same day 8:14:39, 9:16:52, 11:53:34 a. m., 2:28:36 p. m.''—Miss A. M. Hobe.

''At the first shock awake and began to count seconds. Took watch from under pillow counted 10 or 12 seconds when the very heavy shock came and plaster dust began to rain down on the bed. * * * Standing in the doorway and looking out of the east window could see the walls of the brick house shaking * * *''—H. K. Palmer.

''Clock in director's office stopped at 5:12:52 a. m. This clock has a very small and steady rate, was noted as correct within a half minute April 15. Conclusion; violent part of earthquake was between 5:12:22 and 5:13:22.''—J. D. Maddrill.

G. A. Vogt states beginning of shock 5:11:50.

''Time of beginning 5:12:13. Counted for one minute before getting time from watch; heavy vibration still felt at that time, 60 seconds after first count. Motion was felt for nearly a minute longer, or nearly two minutes after first count. The motion was almost entirely horizontal, no vertical movement of consequence was noticed. The waves were very long but smooth. The heaviest seemed to be nearly east and west. Intensity on the R.-F. scale VIII or IX. Water in Smith creek 12 noon was densely milky, light slate color, not yellowish as after heavy freshet.''—C. D. Perrine.

Ewing seismograph north-south pen left plate about one-quarter minute after beginning and returned about one-half revolution

of the plate later. East-west record continuous, though the swing carried pen over edge of plate a number of times. Vertical weight was thrown off its pivots by the violence of the horizontal motions and in consequence shows no displacement after the very start. Barograph seems to have been quite strongly disturbed in the vertical. Duplex seismograph pen was found off the plate on the west side. It seems likely therefore that the duplex recorded only the first 10 or 15 seconds of the shock, if so much as that. Comparison with duplex records from Oakland and Carson bears this out.—J. D. Maddrill.

1906. **April 18**; Los Angeles; moderate shock at 5:16 a. m., lasting between 5 and 10 seconds.—U. S. Weather Bureau.

1906. **April 18**; Southeast Farallon Island, Cal. (26 miles due west of the beach at San Francisco; solid rock rising from the sea; the Weather Bureau building is located 15 feet above sea level). The direction of motion, from the east. A stone weighing about one hundred pounds slid six inches west by south and was rotated slightly in a direction opposite to the hands of a clock. There were two maxima. No vertical motion. No damage done except a crack across the entire front of the fireplace. Two rock slides of about one hundred tons each occurred on west end of the island.

"At 10:06 a. m., April 18, two distinct vibrations were felt. These were felt by Mr. Legler, observer of the Weather Bureau at Point Reyes, distant directly north twenty miles. He was talking to me over the Weather Bureau cable and the vibrations were noted by him 3 seconds before they were felt on the island."—J. A. Boyle, Observer, Weather Bureau.

Santa Rosa; the damage at this point was extensive and the loss of life heavy, owing to the destruction of several hotels. Many brick walls collapsed, chimneys were generally demolished, and frame buildings thrown from their supports.

Petaluma; the damage was considerable; but compared with the destruction at Santa Rosa, distant only a few miles, the loss was small.

Palo Alto; much damage was done by the shock to the newer buildings of Stanford University. The oldest buildings withstood the shock much better. One life was lost.

1906. **April 18**; Eureka.

At Eureka, California.

A. H. Bell, Observer, U. S. Weather Bureau.

According to my office clock, and ink mark on barograph sheet, the shock occurred at 5:11 o'clock in the morning (Pacific time). It was the most severe shock of earthquake of which there is any

record. It lasted 47 seconds and the vibrations were from southwest to northeast. There were no preliminary tremors, the shock being sudden and the vibrations continuous, with the maximum intensity toward the end. Buildings shook to an alarming degree and several were slightly twisted. One frame building moved about 12 inches to the west. Many chimneys toppled over and several hundred panes of glass were broken. There was no loss of life and the loss to property did not exceed $8,000. The chimneys fell in all directions, but most of them towards the west. The statue of Minerva on the dome of the Court House tipped toward the south until it leaned at an angle of 43 degrees.

North of Eureka the shock was slight, and reports indicate that the seismic disturbance did not extend more than thirty miles northward, but south of Eureka the earthquake was more severe. At Ferndale, 22 miles south, several buildings were demolished and many others badly twisted. Naturally there were wild rumors about crevices, upheavals, and depressions in the earth, but upon investigation it was found that such reports could not be verified. With the exception of a few cracks in the subsoil, and possibly a slight depression in some made land, there were no evidences of an earthquake. All the towns along the coast between Eureka and San Francisco were badly damaged. The nearer they are to San Francisco the greater is the damage.

Summing up the situation in Eureka and throughout Humboldt county, the earthquake did not do any considerable damage in the aggregate. The sections to suffer the worst were those on low or filled-in land. I am of the opinion that if our buildings had been higher, or the maximum intensity of the vibrations had lasted 20 seconds longer, the damage in Eureka would have been much greater.

A second shock of earthquake occurred on April 18, at 5:22 a. m. and another was felt at 12:25 p. m. These shocks were slight and of short duration. Slight shocks of earthquake also occurred in early morning of April 19; 3 a. m., 20; 6:07 a. m., 23; 10:30 a. m., 27, and at 11:10 p. m., 30. There was quite a severe shock on April 23, at 1:10 a. m., lasting about 14 seconds. The vibrations were from southerly to northerly, being of sufficient violence to shake buildings and stop clocks in different parts of the city.

1906. **April 18**; American steamer "Mackinaw," coal laden, from Washington to San Francisco, at 5:10 a. m., while in lat. 38° 23′ and long. 123° 24′, experienced heavy shock as if ship had struck bottom three distinct times and then slipped over a shoal. Weather calm, sea smooth, no disturbance of sea.—F. S. Meady.

1906. **April 18**; San Luis Obispo.

1906. **April 18**; Steamer "National City," lat. 38° 24′ N., long. 123° 57′. James Denny, chief engineer, states: "The ship seemed to jump clear out of the water, the engines raced fearfully, as though the

shaft or wheel had gone, and then a violent trembling fore and aft and sideways, reminding me of running full speed against a wall of ice."

AT RIO VISTA.

1906. **April 18**; Rio Vista.

The shake at this point was very severe. It commenced with a number of quite long vibrations from northwest to southeast and wound up with the figure of 8 motion which often accompanies seismic disturbances. It was quite difficult for one to maintain his footing, and, strange to say, nothing was thrown down or overturned, which may be attributed to the gyrating motion. The duration was about 30 seconds, and I am convinced that had it continued 30 seconds longer hardly a house would have been left standing in town. Some lumber piles were thrown down in a lumber yard situated upon a pile wharf, where the disturbance seemed worse than anywhere else. Also the water-tower, 60 feet in height, consisting of two large tanks containing 100,000 gallons, was seen to sway violently. The time of occurrence was 5:13:15 a. m., as determined by myself from stellar observation a few nights before; my clock set to it was stopped upon the above time.—J. C. Stanton, C. E.

1906. **April 18**; Fort Ross.

AT FORT ROSS.

Beginning at the coast three miles south of Fort Ross and running nearly parallel to the coast, at the base of the high hills and back of the table land, is a large crack or fissure. I have followed it for two miles and have heard of it for twenty miles. All fences and a water-pipe line crossing this fissure show positively that there has been a slip sidewise of about eight feet. The width or spread of the fissure and the rise and fall of the ground vary.—G. W. Call.

Ferndale, California; 5:13 a. m. Most severe shock ever experienced here. Nearly all business buildings damaged, some very badly. The ground opened and in places sank as much as 3 feet. Bureaus, clothes-presses, piano-players, thrown down, and two pianos reported thrown over. A standing chimney top was a novelty after the quake. The shock came from about 15 degrees south of west and the severe portion of it lasted about 25 seconds.—J. A. Shaw, C. E.

1906. **April 18**; Napa.

AT NAPA STATE HOSPITAL.

At 5:14 a. m. on the morning of the 18th of April, 1906, a severe earthquake commenced and lasted about 80 or 90 seconds. The apparent motion at the beginning was from the west-south to

the east-north, a rolling motion for about 15 to 20 seconds, then a light interval for a few seconds, then a renewed force of a twisting nature, intensity IX+.

The ground, to the eye, seemed to be quivering, the hills seemed to have a rocking motion, the trees seemed to be shaken by the hands of a giant, everything looked to be in motion; the air was hazy and still.

Many brick and stone walls were thrown to the ground and others damaged to such an extent that they will have to be taken down. Nearly all chimneys were thrown down, and of those standing some are turned a quarter way round. Milk in pans was thrown out in an easterly and westerly direction.

The estimated damage to the city of Napa is about $150,000.

The damage to this institution was very light, except that the main tower will have to come down.—W. H. Martin.

Spokane, Washington; no shock felt at Weather Bureau office; but an abnormal jarring movement was found recorded on all the recording devices in the office at 5:12 a. m. The clock on triple register was working properly at 5 a. m., but at 6 a. m. it was found to be 25 minutes behind time.—C. Stewart, U. S. Weather Bureau.

Paisley, Oregon. "Earthquake shocks were reported at Marshfield and Paisley, but no details were given."—E. A. Beals, U. S. Weather Bureau, Portland, Ore.

1906. **April 18**; San Diego; 4:29:45 p. m. Force III; vibration southwest to northeast. Lasted 20 seconds; most severe shock in years.

Phœnix, Arizona; slight shock occurred about 5:48 a. m.; motion west to east.—U. S. Weather Bureau.

Yuma, Arizona; 4:30 p. m. Slight rolling vibration from east to west.—S. Hackett, U. S. Weather Bureau.

1906. **April 19**; Oakland, Chabot Observatory. Observer, C. B. Seven shocks between 6 a. m. and 2:15 p. m.; duration 2 to 3 seconds; intensity II-III.

Los Angeles; moderate shock at 12:31:41 p. m.

Points in western Nevada; 8:15 p. m. This list reported by Prof. George D. Louderback, University of Nevada, Reno:

Hazen; windows rattled; gas jets swung north to south.

Olinghouse; windows rattled; crowd in hotel bar-room scared and ran outside.

Wadsworth; sharp, quick shock like a blast; windows rattled.

Finley; quite strong in tent. Mr. Post at Reclamation Service Camp.

Carson Dam, 12 miles west of Fallon; shock plainly felt.

Brown's Station; men preparing for bed scared and ran out of house.

Not felt at Reno, Fallon, Lovelocks, and east.

The time was variously given as about 8, about 9, somewhat after 8 and between 8:30 and 9 p. m. Mr. L. H. Taylor, engineer in charge at Survey Camp, gives 8:15 as the time, and the more reliable reports confirm this.

Eureka; early morning.

1906. **April 20**; Oakland, Chabot Observatory. Moderate shock in afternoon.

Napa; 4:50 a. m.

Eureka; slight shock 3 a. m. Vibrations from south to north, lasted about 3 seconds.

1906. **April 21**; Napa; 3:00 a. m.—W. H. Martin.

1906. **April 22**; Oakland, Chabot Observatory. Time 3:18:22 p. m.; duration 2 seconds; direction from east; intensity III.—Observer, C. B.

Napa; 3:00 p. m.—W. H. Martin.

San Francisco; sharp shock 3:19:30 to 3:19:34, about 4 waves, moderate rocking.—A. G. McAdie.

1906. **April 23**; Oakland, Chabot Observatory. Time 8:10:10 a. m.; duration 3 seconds; direction from east; intensity III. Second shock 10:55:00 p. m.; intensity II.—Observer, C. B.

San Francisco; 3:51 p. m., about 1 second. Second shock 10:34 p. m., moderate shock.—A. G. McAdie.

Eureka; quite a severe shock at 1:10 a. m.; duration 14 seconds. Vibration from south to north. Sufficiently violent to shake buildings and stop clocks. Slight shock at 6:07 a. m. Vibrations from south to north, and lasted 4 seconds.

Ferndale; at 1:11 a. m. Severe shock, over-turning movable objects, chimney tops, etc. It came from about the same direction as on 18th. Duration 10 seconds.—J. A. Shaw, C. E.

1906. **April 23**; Ferndale; 6:30 a. m. Smart shocks of three seconds' duration.—J. A. Shaw, C. E.

1906. **April 24**; Oakland, Chabot Observatory. Time 10:45:00 p. m., and again at 11:42:00 p. m.

San Francisco; 1:25 a. m., short shock. 1:32 a. m., 2 (?) a. m., 1:14 p. m., light throw.—A. G. McAdie.

1906. **April 25**; San Francisco; 4:30 a. m.—A. G. McAdie.

Oakland, Chabot Observatory. Time 6:30:22 a. m.; duration 3 seconds; direction northeast to southwest; intensity III. Second shock 3:15 p. m.; duration 3 seconds; intensity III.—Observer, Prof. C. Burckhalter.

Niles; 3:22 p. m. And many shocks during month.—Wm. Barry.

Napa; 3:15 p. m. Sharp.—W. H. Martin.

Lick Observatory; 3:17:40 p. m.

San Francisco; 3:17:10 p. m. Double swing. Recorded on seismograph at No. 3018 Clay street. Slight horizontal motion. — W. R. Eckart and A. G. McAdie.

1906. April 26; Oakland, Chabot Observatory. Time 10:29:55 a. m. Explosion.

Lick Observatory; very slight shock 10:33:35 a. m., jolt only, no swing.—Professor Tucker.

1906. April 27; Oakland, Chabot Observatory. Time 6:15 a. m. Intensity II. Again at 1:08:10 p. m.; duration 3 seconds; direction east to west; intensity III.

Eureka-Ferndale; sharp shock at 10:30 a. m.

1906. April 28; Napa; 12:35 a. m. Sharp.—W. H. Martin.

1906. April 29; Lick Observatory; 4:09:21 p. m. Northwest and southeast; duration 1 or 2 seconds.—Dr. Campbell.

San Francisco; 4:09 p. m.—A. G. McAdie.

1906. April 30; Oakland, Chabot Observatory. Time 1:00 a. m. and 7:20 a. m. Shocks from this date until May 17 seemingly of circular motion, no decided direction shown by seismograph. They were in the nature of tremors with vertical motion predominating.— Observer, Prof. Chas. Burckhalter.

San Francisco; 1:57:30 a. m., and again at 1:59:40, and again 7:10 a. m.—A. G. McAdie.

Eureka; slight shock reported to have occurred at 11:10 p. m.

1906. May 1; Cloverdale, Napa, Peachland.

Napa; three light shocks reported.—W. H. Martin.

1906. May 2; Calistoga, Napa, Oakland, Laurel.

Oakland, Chabot Observatory. Time 6:56:20 a. m.; intensity II.

Napa; 12:35 a. m. Sharp.—W. H. Martin.

San Francisco; 6:51:30 a. m., light shock, and again at 8:50 a. m., and again 9:22 a. m.—A. G. McAdie.

Lick Observatory; 4:51:12–14 p. m. R.-F. I.—Dr. Perrine.

1906. May 3; San Francisco; 6 a. m., light, and again at 9:41:22 a. m.— A. G. McAdie.

Oakland, Chabot Observatory; 6:00:20 a. m.

Glenwood.

1906. **May** 4; Campbell.

Lick Observatory; 5:25 a. m. R.-F. II. Duration 5 seconds. Two distinct principal shocks one-half second apart, 3 seconds after beginning; direction north to south (?). No vertical vibration felt; no sound heard.—J. G. Maddrill.

San Francisco; 5:32 a. m. Feeble shock.—A. G. McAdie.

San Francisco; 10:29:30 a. m. Sharp jar.—A. G. McAdie.

1906. **May** 5; Oakland, Chabot Observatory; 10:28 a. m.

Napa; 10:30 a. m.—W. H. Martin.

San Francisco; sharp jar, 10:29:30 a. m.—A. G. McAdie.

Lick Observatory; 10:30:05 a. m. Duration 1 second, very faint.—Dr. Campbell.

1906. **May** 6; San Francisco; slight shock. 7:29 a. m. and again at 8:59:20; last one double wave and felt like a push, then more waves.—A. G. McAdie.

Blocksburg, Ukiah.

1906. **May** 7; San Francisco; several light tremors during the night and early morning. Shock at 5:07 a. m., another sharp shock at 4:17:10 p. m.—A. G. McAdie.

1906. **May** 8; San Francisco; 12:12 p. m. and 11:42 p. m. Sharp.—A. G. McAdie.

Campbell, Salinas.

1906. **May** 9; San Francisco; 5:20 a. m.—A. G. McAdie.

Salinas.

Ferndale; 9:30 p. m. Slight shock of 3 seconds' duration.—J. A. Shaw, C. E.

1906. **May** 9; Eureka; slight shock about 7:25 p. m., lasting several seconds. Vibrations south to north. Shook windows.

1906. **May** 10; Blocksburg, Zenia, Laurel, Montague.

San Francisco; 12:15 a. m.—A. G. McAdie.

Eureka; slight shock 6:59 a. m. Sudden jolt; duration 4 seconds. Vibrations south to north.

Ferndale; 6:55 a. m. Slight shock; 3 seconds.—J. A. Shaw, C. E.

1906. **May** 11; Oakland, Chabot Observatory; 1:27:46 p. m.

Napa; 1:30 p. m. and 3:30 p. m.—W. H. Martin.

San Francisco; 1:30:49 p. m. Heavy shock, lasting 3 seconds.—A. G. McAdie.

Kentfield, Salinas.

1906. **May** 14; Campbell.

1906. **May** 14; San Francisco; 5:21 p. m. and again at 9:03 p. m.—A. G. McAdie.

1906. **May** 15; Lick Observatory; 11:56:46-48 a. m. R.-F. III. Duration 5 seconds ending with a jolt.—Mrs. R. G. A.

1906. **May** 16; Heber.

Ferndale; 5:20 a. m. Moderate shock; 3 seconds.—J. A. Shaw, C. E.

1906.—**May** 17; Oakland, Chabot Observatory, 8:20 p. m.

Napa; 8:21 p. m.—W. H. Martin.

San Francisco; 11:05:45 a. m. and again at 8:24:30 p. m.—A. G. McAdie.

Lick Observatory; 8:21:24 p. m. Mrs. T. called attention to shock 3 or 4 seconds at least before I noticed it. I first felt it at 8:21:24 light for 2 seconds then heavy for 2 to 3 seconds, heavy part beginning 8:21:26. Possible error 3 seconds.—Dr. W. W. Campbell.

Campbell, Gonzales, Imperial, Livermore, San Luis Obispo.

Ferndale; 3:40 a. m., and 2 more before 6 a. m.—J. A. Shaw, C. E.

1906. **May** 18; Blocksburg, Ft. Bragg.

San Francisco; 5:23 a. m. Light shock.—A. G. McAdie.

Ferndale; 8:55 p. m. Slight shock, 2 seconds.—J. A. Shaw, C. E.

1906. **May** 19; Lick Observatory; 2:32:10 a. m. R.-F. III. Slight motion east and west.—Dr. Campbell.

Blocksburg, Ft. Bragg, Campbell.

Ferndale; 4:47 a. m. Very slight shock.—J. A. Shaw, C. E.

1906. **May** 20; Ft. Bragg.

1906. **May** 22; Ferndale; before daylight. Very light.—J. A. Shaw, C. E.

1906. **May** 30; San Francisco; 12:37:20 (?). Very feeble.—A. G. McAdie.

1906. **May** 31; San Francisco; 5:50 a. m.—A. G. McAdie.

Napa; 5:45 a. m.—W. H. Martin.

1906. **June** 4; Oakland, Chabot Observatory. Time 11:50:50 p. m. Duration 3 seconds; direction southwest to northeast; intensity III.

Niles; 11:55 p. m.

San Francisco; 11:52 p. m.—A. G. McAdie.

Berkeley; 11:51:07 p. m., 11:51:45 p. m.—A. O. Leuschner.

Campbell, Mills College, Napa.

Ferndale; 9:40 p. m. Very slight shock.—J. A. Shaw, C. E.

1906. **June** 7; Ferndale; 4:13 p. m. Slight shock, about 15 seconds duration.—J. A. Shaw, C. E.

Blocksburg, Ft. Bragg, Upper Mattole.

Berkeley; 12:21:39 a. m.

1906. **June** 7; Eureka; heavy shock at 4:15 p. m., lasting 26 seconds. Vibrations from a little south of west to east, of sufficient violence to shake buildings. The shock came suddenly with greatest intensity a few seconds after the first shock was felt, and then gradually died away. This was the most severe shock since morning of April 18.—A. H. Bell, observer, U. S. Weather Bureau.

1906. **June** 8; Fort Ross.

1906. **June** 9; Ft. Ross, Mills College.

San Francisco; 7:41 p. m.—A. G. McAdie.

1906. **June** 10; Ferndale; 6:26 p. m. Slight shock, 2 seconds.—J. A. Shaw, C. E.

Eureka, Napa.

1906. **June** 13; Eureka; very light shock, 11:50 a. m.

Tequisquita Rancho, Campbell.

Ferndale; 11:51 a. m. Very light.—J. A. Shaw, C. E.

1906. **June** 14; Ferndale; 4:50 a. m. Very light.—J. A. Shaw, C. E.

1906. **June** 15; Oakland, Chabot Observatory. Time 9:39:45 p. m. Duration 3 seconds; direction from northeast; intensity III.

Niles; 9:42 p. m.—Wm. Barry.

Napa; three shocks reported.—W. H. Martin.

Lick Observatory; Ewing instrument started. Shock felt by no one. Slight record on duplex.—E. Smith.

Ft. Bragg, Livermore, Mills College, Peachland, Sonoma.

San Francisco; 9:41 p. m. and again at 10:35 p. m.—A. G. McAdie.

Berkeley; 9:39:35 p. m., 9:40:52 p. m., 9:41:52 p. m., 9:51:39 p. m., 10:32:04 p. m.—A. O. Leuschner.

Ft. Bragg, 3:40 a. m.; Livermore, 9:45 p. m.; Mills College 9:41 p. m.; Niles, 9:42 p. m.

1906. June 16; Peachland.

Ferndale; 4:50 p. m. and 11:50 p. m. Two very light shocks.—J. A. Shaw, C. E.

1906. June 18; Fort Ross.

1906. June 20; Ferndale; 8:10 a. m. Very light.—J. A. Shaw.

1906. June 22; Berkeley; 11:51:03 p. m., 11:51:10 p. m.—A. O. Leuschner.

San Francisco; 6:07 a. m.—A. G. McAdie.

Mt. Tamalpais, Kentfield.

1906. June 25; Ferndale; 9:16 a. m. Light shock of about 6 seconds duration.—J. A. Shaw, C. E.

1906. June 26; Napa, Peachland.

1906. June 27; Ft. Ross.

1906. June 28; Peachland.

1906. June 30; Upper Mattole. Mr. W. H. Roscoe states that since the 18th of April there have been at least one hundred shocks.

1906. July 1; Mt. Tamalpais.

1906. July 2; Fort Bragg; 5:45 a. m.

1906. July 4; Lick Observatory; 5:39 a. m.—E. A. F.

San Francisco; 1:15:30 p. m. Single swing.—A. G. McAdie.

Salinas, 5:45 a. m.; Campbell, 5:45 a. m.

1906. July 6; Lick Observatory; two light shocks, 10:32 a. m. Three vibrations felt; duration 1 second. 10:55 p. m., light east to west.—Professor Aitken.

Berkeley; Omori seismograph at Students' Observatory, recorded the shock at 10:52:15 $\pm$ 2 seconds, p. m., and again at 10:58 p. m. Salinas, 10:52 p. m.

Los Banos.

San Luis Obispo.

1906. July 9; Eureka; 10 p. m., 11:37 p. m.

Ferndale; 11:40 p. m. Very light.—J. A. Shaw, C. E.

1906. July 12; San Francisco; 5:38 a. m. (?)—A. G. McAdie.

Mt. Tamalpais.

1906. July 13; Sierra Madre; 5:20 a. m. Newhall 5:35 a. m.

Los Angeles; moderate shock felt at 5:30 a. m.—U. S. Weather Bureau.

1906. **July** 18; San Francisco; 6:27:35 p. m.—A. G. McAdie.

1906. **July** 20; San Francisco; 1:20 a. m.—A. G. McAdie.
Berkeley; 1:19:36 a. m.—A. O. Leuschner.
Mt. Tamalpais.

1906. **July** 21; San Luis Obispo.

1906. **July** 22; San José; 10:39:30 p. m., 11:48:20 p. m.—H. F. Reid.

1906. **July** 23; San José; 5:41 a. m.—H. F. Reid.
Helen Mine; 11 p. m.

1906. **July** 24; Imperial; 6 p. m.

1906. **July** 25; San José; 11:04:30 p. m.—H. F. Reid.

1906. **July** 26; Mills College; 9:20 p. m.
Berkeley; 9:18:30 p. m.—A. O. Leuschner.
San José; 4:37:30 a. m.—H. F. Reid.

1906. **July** 27; Pt. Loma; 10:10 p. m.

1906. **July** 28; Berkeley. Prof. H. Fielding Reid reports light shocks at 0:22:40 a. m., 5:25 a. m., 5:44 a. m., 6:01 a. m., 7:25 a. m., 7:46 a. m.

1906. **July** 29; Berkeley. Prof. H. Fielding Reid reported light shock at 6:46:20 a. m.

1906. **July** 30; Eureka; light shock 6:45 p. m.
Berkeley; 5:35 a. m.—H. F. Reid.

1906. **August** 1; Eureka; light shock at 11:32 a. m. Vibrations from southwest. Duration about 2 seconds.
Ferndale; 11:31 a. m. Very light.—J. A. Shaw, C. E.
Peachland; 6 a. m. Light.
San Luis Obispo.

1906. **August** 2; Berkeley; 6:15:05 a. m. Recorded on Omori seismograph.

1906. **August** 2; Fort Ross; 6:04 a. m.—G. W. Call.

1906. **August** 3; Fort Ross; 5:02 p. m.—G. W. Call.

1906. **August** 3; in latitude N. 25° 35′, longitude W. 110° 06′, ship "Alex. Gibson," Capt. J. A. Wayland, experienced a tremendously heavy shock lasting about 40 seconds, shaking the ship from stem to stern as if she were bumping over a ledge of rocks; it shook tools out of the racks in the carpenter shop, pots and pans down in the galley and cups and pitchers from hooks in the pantry and all lamp glasses off the lamps. The crew came running aft, not knowing what was the matter and the captain thought the yards were coming down. The sea at the time was perfectly smooth, wind light from the southwest. No land in sight; all sails set

in fine clear weather. At 7:10 p. m., ship's time, felt another light shock of about 15 seconds duration and from 8 to 12 midnight felt two more very light shocks; but did not note the time. The captain states that he had experienced an earthquake at sea on a former occasion so he knew what it was; but the one felt before was nothing to this one either in force or duration.—J. T. McMillan.

1906. **August** 4; Berkeley; 11:19 p. m.
Lick Observatory; 5:39 a. m. I.

1906. **August** 5; Berkeley; 1:53 a. m., 3:25 a. m., and 6:15 a. m.—Prof. A. O. Leuschner.

1906. **August** 5; Fort Ross; 1:50 p. m.—G. W. Call.

1906. **August** 6; Lick Observatory; 10:32:2 a. m. II.

1906. **August** 12; Rio Vista; 6 a. m.

1906. **August** 14; Salinas; 8:30 a. m. and 9:35 a. m. Light.

1906. **August** 15; Tequisquita Rancho; 4:40 a. m.

1906. **August** 16; Berkeley; 4:17:58 p. m. Recorded on Omori seismograph. This is the "great Valparaiso earthquake."

1906. **August** 19; San Francisco; 9:00 a. m. Tremor and jolt.—A. G. McAdie.

1906. **August** 19; Tequisquita Rancho; 2 a. m.
Salinas; 1:59 a. m. Sharp.

1906. **August** 21; in the Gulf of California. Latitude N. 26° 19″, longitude W. 110° 25″ at 2:15 p. m.; duration 1 minute. The vessel trembled and the sensation was as if the ship were bumping on rocks. Shock felt by all hands. Bark, "St. James;" Captain, F. O. Parker. On arrival at Guaymas, shortly afterward, inquiry made if shock had been felt there but none had been noted.—J. T. McMillan.

1906. **August** 22; Napa; 1:55 a. m.—W. H. Martin.

1906. **August** 25; Ferndale; 1:40 p. m. Light shock.—J. A. Shaw, C. E.

1906. **August** 26; Ferndale; 9:09 p. m. Light shock; 3 seconds' duration.—J. A. Shaw, C. E.

1906. **August** 27; Point Loma; 10 a. m.

1906. **August** 28; Ferndale; about 3 a. m.—J. A. Shaw, C. E.
Tequisquita Rancho; 11:40 a. m.

1906. **August** 29; Mt. Tamalpais; 7:59:35 a. m. Vibration southeast to northwest; duration 2 seconds.—W. W. Thomas, Weather Bureau.

1906. **August** 30; Sonoma; 2:12 a. m. Light.

1906. **August** 31; Ft. Ross; 9:52 a. m.

1906. **September** 1; Sonoma; 3:12 a. m. Light shock.

Tequisquita Ranch; 5:50 a. m.

1906. **September** 2; in latitude 43° 40′ N., longitude 128° 50′ W. Bark "Agate," Capt. C. H. McLeod. Experienced a heavy shock, lasting nearly a minute; sensation being as if the vessel had struck a coral reef or rock. The wind was northwest and light; weather clear, sea smooth, barometer 30.00. At 3:55 a. m. felt another shock, not quite so severe as the first, nor of as long duration.—J. T. McMillan.

1906. **September** 6; Branscomb; 12:10 a. m.—A. J. Haun.

1906. **September** 7; Lick Observatory; 9:24:59 a. m. II-III. Perceptible vibration; duration about 10 seconds. One slight jolt. Duplex indicated slight east-west motion.

1906. **September** 8; Berkeley; 12:32 p. m.—Prof. A. O. Lauschner.

1906. **September** 9; Carson City, Nevada. A light earthquake at 4:55 a. m.—C. W. Friend.

Wabuska, Nevada; a tremor about 5 a. m.—J. G. Young.

Grass Valley, California; 4:15 a. m.—I. Sanks.

Nevada City, California; 5 a. m. Was quite generally felt in Grass Valley and Nevada City. It was of short duration; but very distinct.—Sherman W. Marsh.

Pilot Creek; 4:55 a. m. Two distinct shocks.—E. W. Stanton.

1906. **September** 13; Ferndale; 8:45 p. m. Short.—J. A. Shaw, C. E.

1906. **September** 14; on board schooner "Robert Searles" in latitude N. 41° 18′, longitude W. 125° 52′; severe earthquake or other submarine disturbance; duration 25 seconds; time, 11:30 a. m.; it shook vessel considerably; weather unsettled and sun extremely hot when visible.—Capt. J. H. Piltz and J. T. McMillan.

Berkeley; 8:46 a. m. Recorded on Omori seismograph at Students' Observatory.

1906. **September** 16; Lick Observatory; 7:12:02 a. m. III (?). Observers noting direction agree on north-south. Duplex showed E. 30° S.

1906. **September** 17; Ferndale; 5:15 p. m., lasted 10 seconds; and again at 8:10 p. m.—J. A. Shaw, C. E.

1906. **September** 18; Ferndale; 8:45 p. m.—J. A. Shaw, C. E.

1906. **September** 20; Berkeley; 11:39 p. m.—Prof. A. O. Leuschner.

1906. **September** 21; Berkeley; 11:24 p. m.—Prof. A. O. Leuschner.

1906. **September** 25; Berkeley; 5:36 a. m.—Prof. A. O. Leuschner.

1906. **October** 5; San Francisco; 6:30 a. m.

1906. **October** 7; Fort Ross; 11:57 p. m.—G. W. Call.

1906. **October** 10; Tequisquito Rancho; 5:45 a. m.
San Francisco; 11:45 p. m.

1906. **October** 11; Salinas; 5:30 a. m.

1906. **October** 17; Fort Ross; during night.—G. W. Call.

1906. **October** 18; Tequisquito Rancho; 5 a. m.

1906. **November** 6; 8 a. m., latitude 46° 09′ N., longitude 125° 32′ W. American schooner "Stanley." Willapa Harbor to San Francisco. Heavy southerly gale blowing and heavy swell on, when suddenly wind died down to a calm, but swell still continued. About the time when wind dropped to a calm, felt a sharp earthquake shock lasting about two or three seconds. Immediately afterwards we were looking toward the southwest, when we saw mountainous waves coming toward us; when they struck the vessel she began to pitch and roll violently, and we thought every minute we would be swamped. In the midst of the confusion all the sailors became alarmed and took to the rigging. I immediately began using oil to help calm the seas and to protect the vessel from serious injury. The wind finally sprang up from the northwest, light, hazy, and misty. Barometer 28:60 inches. The dangerous seas lasted for about one hour and thirty minutes. The mate was certain that the mountainous seas were caused by the earthquake shock.—K. Peterson and K. Magensen.

1906. **November** 11; American bark "Carondelet," Capt. Thomas Doyle. Latitude 42° 51′ N., longitude 127° 31′ W. 6:40 a. m. I felt a quick rolling sensation, and a few seconds after felt the ship tremble fore and aft. I thought at the time that we had run on top of some sunken vessel or a whale. It looked like a heavy tide rip all around the vessel. The second shock was light. As to the tides, for 24 hours after had about one-half mile per hour. Bound from Port Gamble to San Francisco; experienced very rough weather for 11 days; nothing but gales from southeast round to southwest.

1906. **November** 4; Fort Ross; 11:58 a. m.

1906. **November** 7; Eureka.

1906. **November** 9; Fort Bragg; 2 a. m.

1906. **November** 12; Salinas in a. m. Light.

1906. **November** 13; Fort Bragg; 3 a. m.
Glenwood; 7:48 p. m.
Tequisquito Rancho; 7:48 p. m.
San José; 7:48 p. m. Sharp, lasting 3 seconds; east to west.
Lick Observatory; 7:47:49 p. m. One jolt north-south direction.

1906. **November** 14; Fort Bragg; 2:30 a. m.
Fort Ross; night of 14-15.

1906. **November 22**; Isabella; 10:45 p. m.

Glenwood; 3:53 p. m.

1906. **November 25**; San Francisco; 1:15 p. m. Very light.

1906. **November 26**; San Francisco; 1:50 a. m. Very light.

1906. **November 26**; American steamer "Newport." Position 14° 41′ N., 92° 36′ W. Time 10:27 p. m. Felt sharp shock lasting about 8 or 10 seconds. Shook the steamer considerably, frightening passengers. Weather clear, barometer 29:24, temperature 83, temperature of water 83 and sea smooth.—W. J. Russell and A. Koppe.

1906. **December 6**; San Luis Obispo; 10:40 p. m. Duration 30 seconds; from north to south. A second shock an half hour later. Felt also at Santa Maria.

Tequisquito Rancho; 6:45 a. m.

1906. **December 7**; San Miguel; 10:55 p. m. Followed by slight tremble for 15 seconds.

1906. **December 8**; Idyllwild; 10:40 a. m.

Mt. Tamalpais; 5:48:54 p. m. Light shock, lasting 2 seconds.

1906. **December 9**; San Francisco; 3:20 a. m. Intensity about III on R.-F. scale. Duration a few seconds; one marked wave from southwest to southeast.—A. G. McAdie.

Oakland, Chabot Observatory. Time 3:20:40 a. m.; duration 6 seconds; direction northeast to southwest.—Prof. Charles Burckhalter.

Mills College; 3:20 a. m.—Josiah Keep.

Berkeley; Students' Observatory. Seismograph recorded heaviest shock since last June. Duration 6 seconds. Movement from southwest to northeast.—Prof. A. O. Leuschner.

1906. **December 19**; Cuyamaca; 3 p. m.

Escondido; 2:46 p. m. Light.

1906. **December 22**; Calexico; 8:45 a. m.

1906. **December 23**; Calexico; 4:55 a. m.

Cuyamaca; 4 a. m.

Fort Ross; 5:48 a. m.

Berkeley; 9:26:35 a. m. Seismograph recorded a distant shock; origin probably not less than 2,300 miles nor more than 4,000 miles distant.—A. J. Champreux.

1906. **December 24**; Napa; 2 a. m. Sharp jar.

1906. **December 25**; Eureka; 8:18 p. m. Short. In some parts of city vibrations strong enough to upset vases.

Rohnerville; 8:15 p. m.

1906. **December 28**; Lytle Creek; early morning. Light.